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**THERMAL ANALYSIS OF PANSAT BATTERIES AND ELECTRICAL  
POWER SUBSYSTEM**

by

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Submitted in partial fulfillment  
of the requirements for the degree of

**MASTER OF SCIENCE IN ASTRONAUTICAL ENGINEERING**

from the

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**September 1994**





## ABSTRACT

The thermal design of a spacecraft ensures proper heat transfer so all components and subsystems remain within prescribed temperature limits during all aspects of the spacecraft's mission. This thesis develops a point-to-point heat flow model of the Electrical Power Subsystem (EPS) and its associated housing for the Petite Amateur Navy Satellite (PANSAT). The analysis is performed to identify physical locations in the EPS where temperature may exceed the limits established to protect sensitive electronic components, and to define the expected environment of the batteries. The Integrated Thermal Analysis System (ITAS) and a Steady State Thermal Analyzer and Model Builder were used to perform steady state and transient analyses on the EPS; analysis of the batteries was performed using ITAS only. The simulated transient temperatures within the EPS housing remained within limits, but the batteries exceeded specifications. It is suggested that a passive thermal control technique be adapted for the batteries and its design be experimentally validated before flight.



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# **I. INTRODUCTION**

## **A. REASON FOR ANALYSIS**

The thermal environment for components within a spacecraft is a function of the irradiation from the sun and earth, internal heat dissipation, radiation from external surfaces to the space sink, and the conductive and radiative heat transfer paths between the heat sources and sinks. Thermal control design ensures proper heat transfer so that all components and subsystems remain within prescribed temperature limits during all aspects of the spacecraft's mission.[Larson and Wertz, 1992] Early thermal design forces the determination of operating temperature limits and identifies the power dissipation patterns of components to allow for maximum use of passive thermal control methods.

To build a thermal model of a spacecraft, a knowledge of dimensions, equipment placement and material properties is required. The spacecraft or area to be analyzed is divided into nodes. The nodes are chosen so that the conductive and radiative heat flow paths accurately represent point-to-point heat flows within the spacecraft.

The thermal design of the spacecraft is also highly dependent on the mission and stabilization system of the satellite. Typically unmanned, low earth orbit spacecraft can be controlled passively. Table 1 lists a typical operating environment for electric power system (EPS) components.

The power subsystem typically has the greatest interaction with the thermal control subsystem because all of the dissipated electrical energy within the spacecraft must be radiated into space. The terrestrial batteries to be used in the Petite Amateur Navy Satellite (PANSAT) have even a narrower temperature range than that listed in Table 1: the ideal operational

SYSTEM COMPONENT	TEMPERATURE RANGE
MILITARY PIECE PARTS FOR INTEGRATED CIRCUITS	-55 TO 125 DEGREES CELSIUS
BATTERIES	-6 TO 26 DEGREES CELSIUS
SOLAR ARRAY PANELS	-100 TO 100 DEGREES CELSIUS

Table 1. Temperature Ranges for Some Electrical Power System Components

temperature for charging and discharging is 23 °C. Operations outside the published temperature range will cause the battery cells to degrade and become less efficient. This condition is explained fully in Chapter VI.

PANSAT has a very low power margin and must be able to maximize the power from the solar arrays and batteries. The sunlight and shadow zones of the orbit require that the batteries must operate for 40 percent of the time. There is only one EPS box for PANSAT. Other vital subsystems are redundant ; for example, the Digital Control Subsystem has two fully capable boxes. The batteries within the Electrical Power Subsystem itself are redundant, but must be able to be recharged to full capacity after each use to ensure proper Depth of Discharge. The batteries and the EPS will be discussed more fully in the following chapters.

## B. SCOPE OF THESIS

The purpose of this thesis is to develop a transient thermal model of the Electrical Power System and the associated housing for the Petite Amateur Navy Satellite (PANSAT) . This thesis will also develop a steady state and transient analysis for the preliminary Nickel-Cadmium battery design, identifying any physical locations within the EPS and batteries where temperature limits are exceeded, and offering some recommendations for

passive thermal methods. Computer generated steady state and transient analyses using radiation, contact conductances and thermal capacitances through the equipment housing and the upper and lower equipment plates of the satellite were used to evaluate temperature ranges at the node points representing physical locations in the structure. To perform the analysis, circuit board layouts, heat dissipations of components, subsystem materials and cell efficiencies were required. Inward viewing box geometry was used to physically model the EPS and the battery model. Two models were used to verify steady state temperatures for the EPS. The transient analyses used equipment plate temperature profiles obtained from a recent transient analysis of the entire PANSAT structure.



## **II. BACKGROUND**

### **A. PETITE AMATEUR NAVY SATELLITE (PANSAT)**

PANSAT was initiated in 1989 to provide interdisciplinary educational opportunities in space related areas to prepare postgraduate students for follow on work in space systems acquisition and design, and to develop a cadre of engineers and technicians at the Naval Postgraduate School (NPS) capable of developing and producing space qualified hardware. The current PANSAT design is the result of five years of research by NPS thesis students and the personnel of the Space Systems Academic Group (SSAG). Preliminary Design Review (PDR) was held in 1993 with the Critical Design Review to be held in late 1994.

The payload will be a direct sequence spread spectrum with a differentially coded, binary phase shift keyed (BPSK) communications system with an operating frequency of 436.5 MHz. The satellite will relay messages on a user-to-user basis in a simplex mode. The store and forward communication will allow amateur radio operators to send and receive messages through several short windows daily.[FRD, 1993]

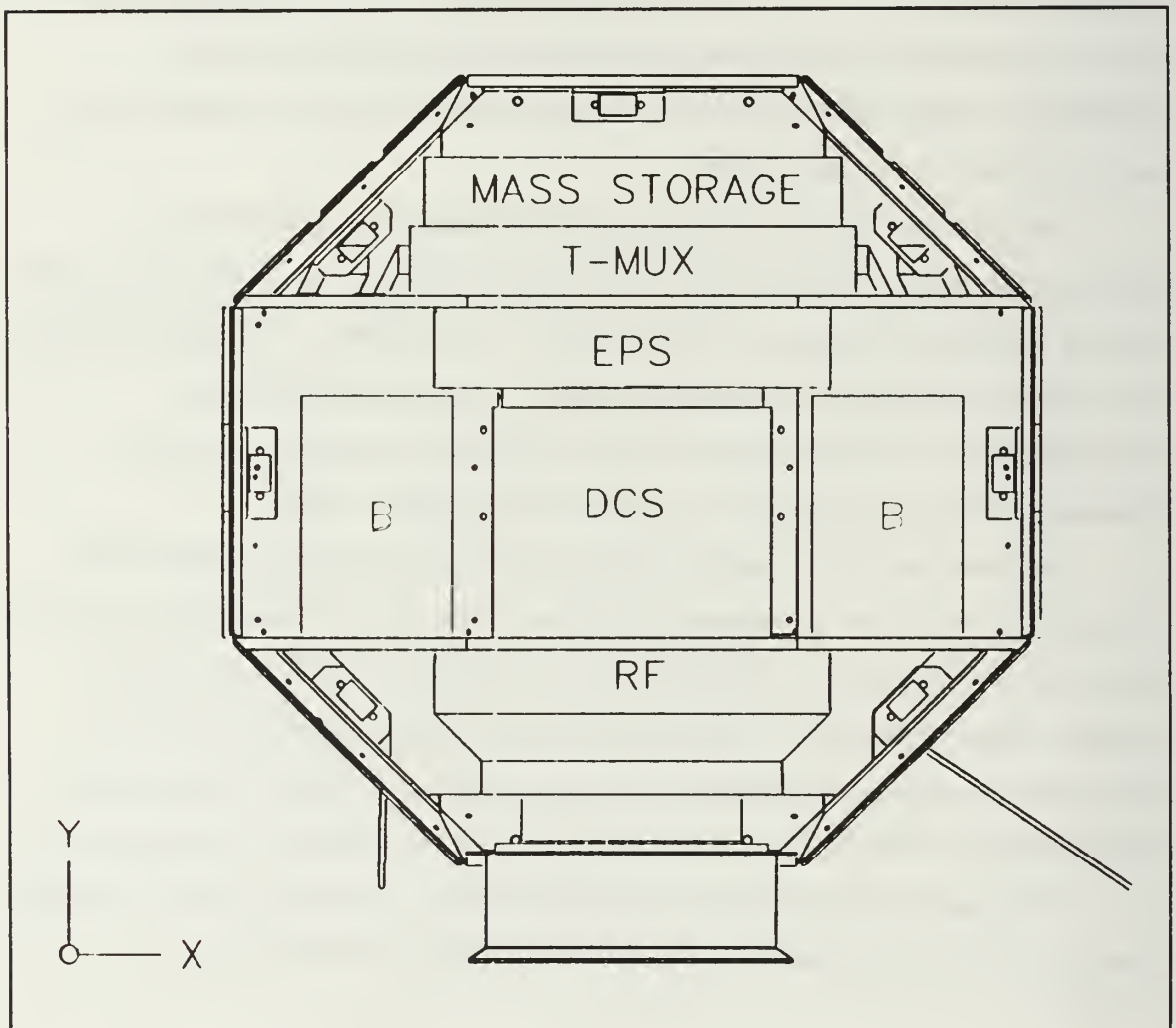
The spacecraft will weigh approximately 150 pounds and is being designed to launch as a secondary platform from the space shuttle as part of the Hitchhiker Program. PANSAT has no attitude control and is free to tumble. Operational life is expected to be two years, with three to five minute communications segments per orbital pass. PANSAT will operate between  $28.5^{\circ}$  and  $51.6^{\circ}$  inclination and between 160-220 nautical miles.

The spacecraft consists of five subsystems: Communication (COMM), Electrical Power, Computer, Structure, and Ground Station Support. This



thesis focuses on the Electrical Power Subsystem, where the thermal control functions reside.

The PANSAT structure is Aluminum 6061-T6, built about a main load bearing cylinder connected to a lower equipment plate. The satellite is a tumbler, and since the solar panels will be mounted on the spacecraft skin, maximizing surface area increases power generation. A 26 sided polyhedron was the chosen structural configuration, already demonstrated on a Shuttle launch. A view of PANSAT is shown in Figure 1.



**Figure 1.** PANSAT Design

## B. ELECTRICAL POWER SYSTEM (EPS)

The power to PANSAT is provided by seventeen 256 cm<sup>2</sup> solar panels consisting of silicon (Si) solar cells. The solar cells are K6700 Si cells connected in series in 4 strings of 8 cells each. The EPS also consists of electrical components needed to generate, regulate, and provide  $\pm 15$  V and +5 V power for the various power control electronics. In eclipse, two Nickel-Cadmium batteries of ten cells each maintain the bus voltage at 12 Vdc. The EPS control interface provides the power switching of all modules on the printed circuit boards (PCBs) in the Digital Control Subsystem (DCS) and COMM. The watchdog timer in the EPS is used to reset the DCS in the event of a failure. The EPS is also dependent on the Ni-Cd batteries for voltage regulation during all modes of operation. An EPS block diagram developed by the SSAG is shown in Figure 2.

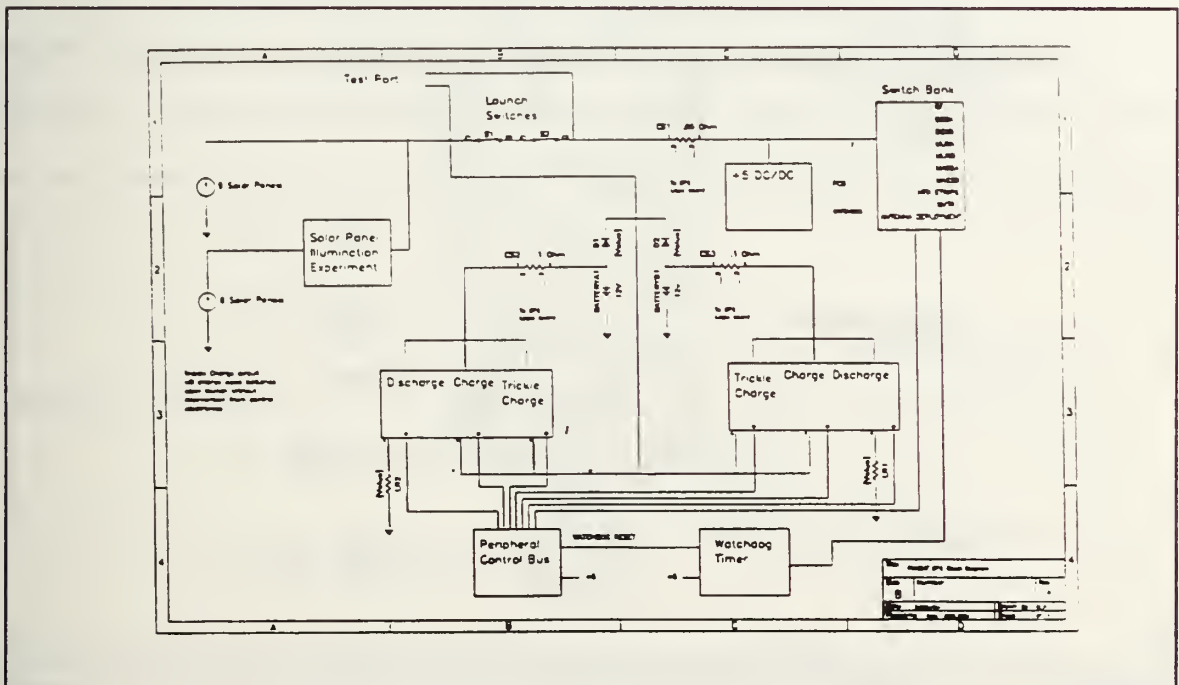


Figure 2. Electrical Power System Block Diagram

Voltage sensors monitor the solar panel bus and battery voltages, and thermal sensors monitor the temperature of the solar panels, batteries and electronics housings. Figure 3 shows the solar panels and box placement. The triangular panels of the satellite do not have solar panels and could be used for passive thermal control if required. The EPS is mounted underneath the upper equipment plate, and above the DCS and batteries, which are mounted on the top of the lower equipment plate.

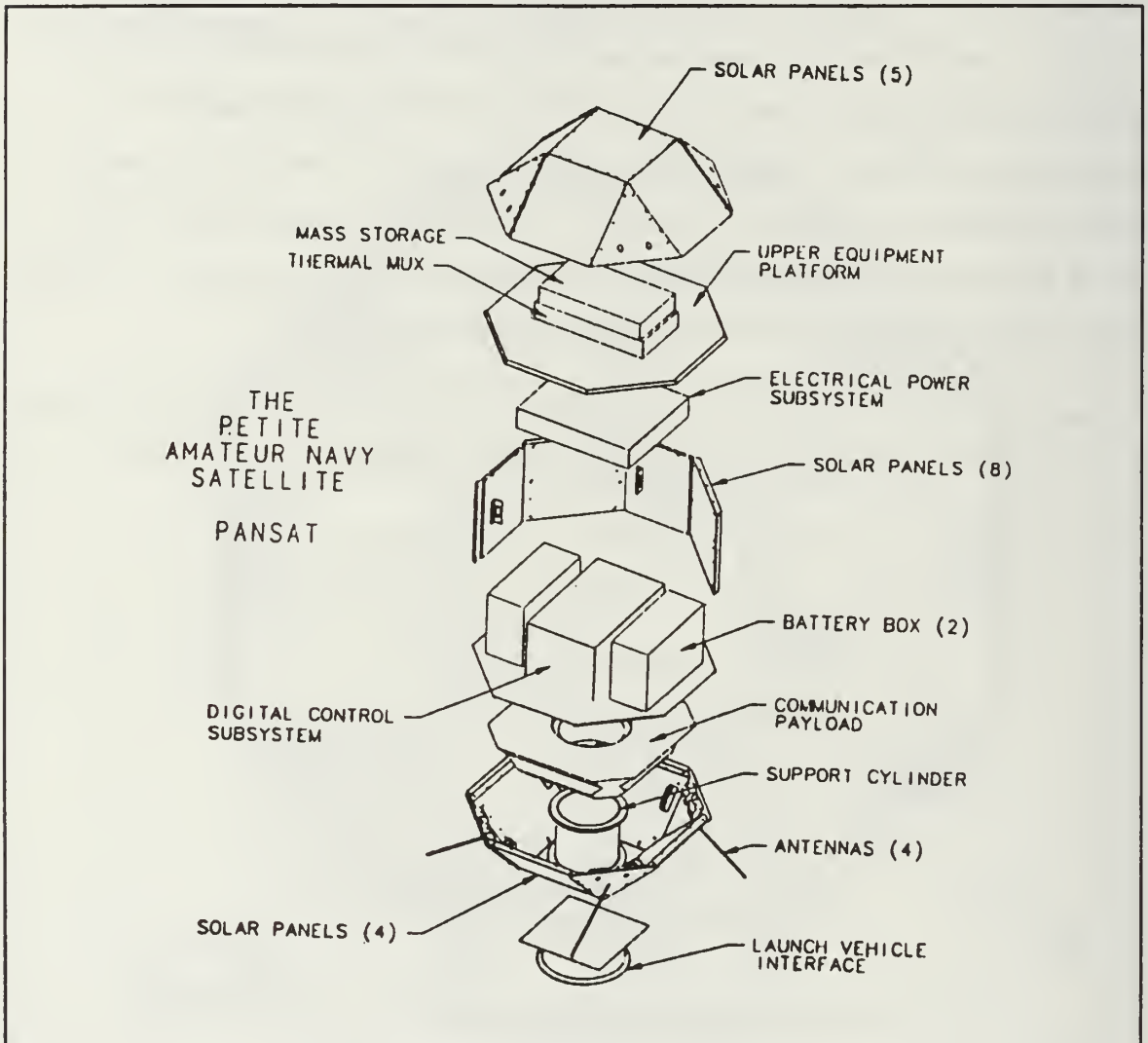
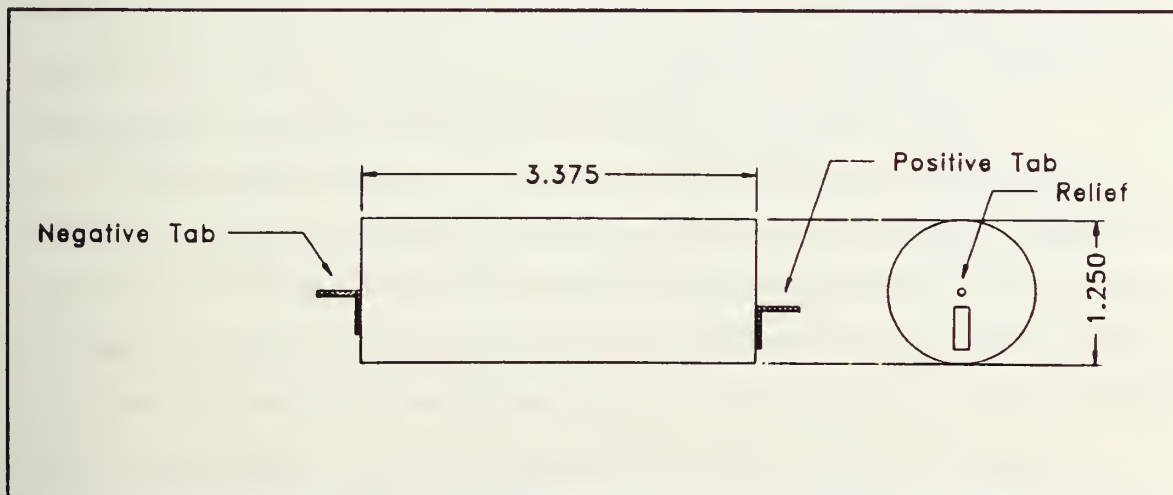


Figure 3. PANSAT Exploded View

PANSAT Design requirements include:

- 21.5 Watts at 15.2 Vdc average minimum electrical power at end of life (EOL)
- Minimum of 60 percent power conversion efficiency
- 12 Volt regulated bus
- Nickel-Cadmium batteries with a 10 percent Depth of Discharge (DOD)
- Mission life of 24 months [FRD, 1993]

Terrestrial Ni-Cd batteries are the chosen type due to high energy density, cycle life and reliability. Space rated batteries will not be used because of their prohibitively high cost. Figure 4 shows the proposed F-cell,



**Figure 4.** Ni-Cd Cell Dimensions

its 32 psi pressure relief valve and the cell dimensions. Although the F-cell has a pressure relief valve it is still considered a closed cell. The batteries will be fully discussed in Chapter VI.



### III. STEADY STATE THERMAL ANALYSIS

#### A. BACKGROUND

A nodal analysis based on a finite difference model of PANSAT structure was performed in 1992 using the Intercept Thermal Analyzer Software Package. Input into the analyzer program is written by a model builder program which can be saved for modification for later use. THANSS is the model builder and the thermal analyzer is TASS. TASS provides the solution of Equation 3.1 using the Cholesky reduction in an iterative scheme

$$[A] \times [T] = [B] \quad 3.1$$

to solve for T (the node temperature vector). THANSS uses conductance paths to generate node to node conductances to form a set of heat balance equations (Equations 3.2, 3.4, and 3.13) where A is the matrix of conductances and B is a column vector of constant temperatures and heat inputs. The node temperatures obtained after each iteration are used to update the temperature dependent terms in the A matrix. This process continues until the change in the nodal temperatures between successive iterations is smaller than 0.05. When the iterative solution is obtained, the temperatures are then written into an output file. [Kraus, 1990]

This analysis resulted in a steady state temperature map of the PANSAT structure (including the square panels where the solar panels are mounted, the triangular panels, and both equipment plates). To accurately model the structure, the square panels were divided into nine equal nodes, the triangular panels were divided into six nodes, and the equipment plates eight nodes each. The model connects the nodes together through a network of user defined conduction paths and connects individual nodes

through constant temperature sinks through conduction and radiation. Results of the steady state analysis for sunlight and shadow zones both with internal heat dissipation are shown in Appendix A.

Conductance values are either calculated or input by the analyst from separate calculations. There are ten different modes that can be selected to characterize node-to-node heat flow. Three of these methods were used for analysis of the Electrical Power System: heat flow between nodes for conduction (method designator 1), heat flow between nodes for radiation (method designator 3), and a constant heat input (method designator 10). The heat balance equation for conduction is

$$q = K_1 (T_2 - T_1) \quad 3.2$$

with the conductance,  $K_1$  determined from the Fourier Law and  $[A] = [K]$

$$K_1 = k \frac{A}{\Delta L} \quad 3.3$$

where  $q$  is the heat flow,  $T_1$  and  $T_2$  define the node-to-node temperature difference for the path,  $k$  is the thermal conductivity of the material in Btu / ft - hr - °F or W/m° C,  $A$  is the cross sectional area for heat flow and  $L$  is the length of the heat flow path. The units of the conductance are Btu/hr ° F or W / ° C.

The heat flow equation by radiation is governed by the Stefan-Boltzmann Law shown in Equation 3.4.

$$q = \sigma F_A F_\epsilon A (T_2^4 - T_1^4) \quad 3.4$$

or

$$q = k_3 (T_2 - T_1) \quad 3.5$$

where

$$K_3 = \sigma F_A F_\epsilon A (T_2 + T_1) (T_2^2 + T_1^2) \quad 3.6$$

Equation 3.6 derives from the fact that  $T_2^4 - T_1^4$  can be written as the sum and difference of squares

$$(T_2^4 - T_1^4) = (T_2^2 + T_1^2) (T_2^2 - T_1^2) = (T_2^2 + T_1^2) (T_2 + T_1) (T_2 - T_1) \quad 3.7$$

Here  $\sigma$  is the Stefan-Boltzmann constant ( $1.713 \times 10^{-9}$  Btu/ft<sup>2</sup>-R<sup>4</sup> or  $5.669 \times 10^{-8}$  W/m<sup>2</sup>-K<sup>4</sup>),  $F_A$  is the arrangement or shape factor and  $F_\epsilon$  is the emissivity factor. For radiation between two non-black surfaces, (where a blackbody is a perfect absorber and emitter of radiation), the emissivity and absorptivity of the surfaces will not be equal to 1. The departure from ideal surfaces for two infinite plates in full view of one another is

$$F_E = \frac{1}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1} \quad 3.8$$

where  $\epsilon_1$  is the emissivity of the first plate and  $\epsilon_2$  is the emissivity of the second plate. [Class notes AA 3804, July 1993] This closely approximates the configuration of the two printed circuit boards (PCBs) in the EPS. The shape factor ( $F_A$ ) accounts for the situation where the alignment of the surfaces prevents the interception of all of the emissions from the source. Other terms used to describe the shape factor include view, configuration and arrangement factor.

For radiation, TASS handles the heat flow by developing  $K_3$  to permit the use of a linear temperature difference ( Equation 3.9)

$$q_r = K(T_2 - T_1) \quad 3.9$$

by computing  $K_3$  from

$$\begin{aligned} K_3 &= \frac{\sigma A F_A F_E (T_2^4 - T_1^4)}{T_2 - T_1} \\ &= \frac{\sigma A F_A F_E (T_2^2 + T_1^2) (T_2^2 - T_1^2)}{T_2 - T_1} \\ &= \frac{\sigma A F_A F_E (T_2^2 + T_1^2) (T_2 + T_1) (T_2 - T_1)}{T_2 - T_1} \end{aligned} \quad 3.10$$

so that  $K_3$  is indeed

$$K = \sigma A F_A F_E (T_2^2 + T_1^2) (T_2 + T_1) \quad 3.6$$

Because heat transfer by radiation is governed by

$$q = \sigma F_A F_E A (T_2^4 - T_1^4) \quad 3.4$$

the conductance value is entered by the user so that

$$q = K(T_2 - T_1) \quad 3.11$$

The user needs only to enter the value

and TASS handles the computation in accordance with Equation 3.6.

$$K = \sigma F_A F_E A \quad 3.12$$

When a node is to have a constant temperature input, a tag of 10 is entered and the connecting node is specified as 999. Thus the third method of heat flow is in the form

$$q = K_q \quad 3.13$$

where  $K_q$  is a constant.

## B. BOUNDARY CONDITIONS FOR EPS ANALYSIS

The steady state structural analysis of PANSAT was conducted in 1992 with the transient analysis of the structure completed in January 1994. The segmented panels (or nodes) were taken individually to determine the number of connections (also known as branches) to other nodes. The type of connection (i.e., the mode of heat transfer for conduction, radiation and constant temperature) is specified as the tag number for the particular branch. Tag is used to avoid confusion between node and mode. Constant temperatures are given node numbers, beginning with 301. A total of 983 conductances from 232 nodes determined the total PANSAT thermal model. When the thermal analysis was run, the first file was a summary of the final temperatures of all the nodes, and was followed by the node temperatures after each iteration.

Models were run for steady state conditions in sunlight and shadow with and without internal heat dissipation. The runs with heat dissipations were used because the satellite low power mode is not much less than the high power mode. Appendix A shows that for the steady state analysis for sunlight with internal heat dissipation the temperatures range from 45.3 °C to 60.2 °C. The steady state analysis in the shadow zone (Appendix B) with



internal heat dissipation resulted in a temperature range of -70.6 °C to 66.6°C.

A transient analysis for the satellite was performed a year later using the same nodes. Average temperatures for the upper equipment plate for the first fourteen orbits are plotted in Figure 5, and for the lower equipment plate in Figure 6. Starting temperature was assumed to be 25 ° C for Kennedy Space Center temperatures in October. Table 2 and Table 3 show the data breakout by node numbers for the upper equipment plate (nodes 211 to 218) and the lower equipment plate (node numbers 219 to 226). The average temperatures for the equipment plates were used as boundary conditions for the transient analysis of the Electrical Power System and the steady state and transient battery analysis.

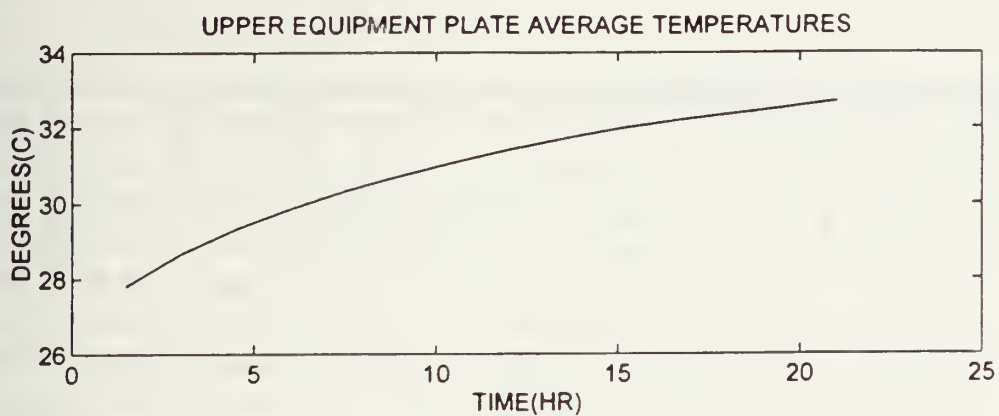


Figure 5. Upper Equipment Plate Average Temperatures

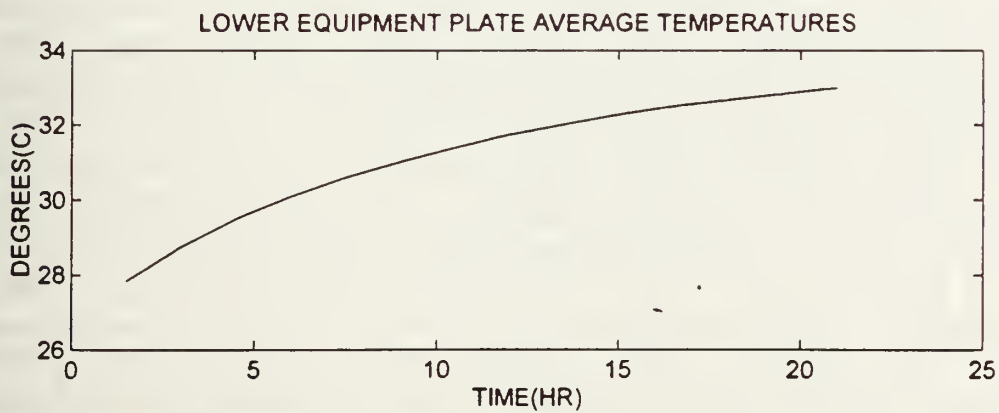


Figure 6. Lower Equipment Plate Average Temperatures

PASS	211	212	213	214	215	216	217	218
1	28.8	29.3	29.3	29.3	27.2	26.9	26.5	26.3
2	28.8	30.4	30.4	29.3	28.1	27.8	27.3	27.1
3	30.5	31.1	31.1	23.0	28.7	28.4	28.0	27.6
4	31.0	31.2	31.7	30.6	29.3	28.9	28.5	28.2
5	31.5	32.2	32.1	31.5	29.8	29.4	29.0	28.7
6	31.5	32.6	32.6	31.4	30.2	29.3	29.4	29.1
7	32.3	33.0	32.5	31.5	30.6	30.2	29.8	29.5
8	32.9	33.3	33.3	32.2	30.9	30.6	30.1	29.8
9	32.9	33.6	33.6	32.5	31.2	30.9	30.4	30.1
10	33.2	33.9	33.3	32.2	31.5	31.1	30.2	30.4
11	33.4	34.1	31.1	33.0	31.4	31.4	30.9	30.6
12	33.8	34.3	34.3	33.2	31.6	31.6	31.1	30.8
13	33.8	34.5	34.5	33.3	32.1	31.4	31.3	31.0
14	34.0	34.7	34.6	33.5	32.2	31.9	31.5	31.2

Table 2. Upper Equipment Plate Temperatures in Degrees C by Node

PASS	219	220	221	222	22●	224	225	226
1	29.2	28.6	29.8	28.2	27.7	27.8	27.8	27.9
2	29.2	29.3	29.3	29.3	28.8	23.0	29.0	28.9
3	30.6	30.7	30.7	30.4	23.6	29.8	29.2	29.7
3	30.6	31.3	31.7	30.7	30.3	30.4	30.4	30.3
6	31.6	31.3	31.4	30.7	30.3	30.4	30.4	30.3
6	31.6	32.3	32.4	31.7	31.3	31.4	31.4	31.3
7	32.0	32.7	32.7	32.1	31.7	31.8	31.6	31.7
8	32.4	33.1	33.1	32.1	32.0	32.2	32.1	32.1
6	32.7	33.4	33.4	32.7	32.3	32.5	32.4	32.4
10	32.9	33.6	33.7	33.0	32.5	32.7	32.7	32.9
11	33.2	33.9	33.6	33.2	32.8	33.0	32.9	32.9
12	33.1	34.1	34.1	33.4	33.1	33.2	33.1	33.1
1●	33.5	34.2	34.3	33.6	33.7	3●.3	33.3	33.2
14	33.7	34.4	34.4	33.8	33.3	33.5	33.4	33.4

Table 3. Lower Equipment Plate Temperatures in Degrees C by Node

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	12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## IV. STEADY STATE ANALYSIS OF THE EPS USING THANSS

### A. PROCEDURE THEORY

A thermal resistance may be defined as the reciprocal of the conductance.

$$R = \frac{1}{K} \quad 4.1$$

R is the resistance in ° F-hr/ Btu or ° C/W. This relationship does not apply exclusively to the conduction mode of heat transfer . If the analogy exists between the heat flow and the direct current statement of Ohm's Law

$$Q = K \Delta T = \frac{\Delta T}{R} \quad 4.2$$

then it is analogous to

$$I = \frac{\Delta V}{R_E} \quad 4.3$$

where  $R_E$  is the electrical resistance and all of the d-c network theorems apply. The addition of thermal resistances in series and the combination of resistances in parallel are permitted operations. For example, the combination of two resistors in series is given by

$$R_C = R_A + R_B \quad 4.4$$

and in parallel where  $R_C$  is the equivalent resistance.

$$R_C = \frac{R_A R_B}{R_A + R_B} \quad 4.5$$

## B. DESCRIPTION OF NODES

To simplify calculations and to assure accuracy in the node descriptions, the printed circuit boards were divided into 72 nodes with each node having an area of 1 square inch. This size results in relatively easy calculations when using areas and lengths between nodes and between printed circuit boards. The top board nodes were numbered 1-72 with the bottom board nodes numbered 73-144. Appendix C shows the node numbering, which will be used for reference later in this chapter.

The boards have six layers, alternating copper and epoxy. It was assumed for the analysis that copper covered 25% of the top layer. This takes circuit board components into consideration. This layer is designated by  $R_1$ . The other two copper layers were assumed to have 100% coverage and are designated by  $R_4$ . The epoxy layers are homogeneous. Figure 7 describes the Node 1 to Node 2 upper board conductances. Appendix 3 shows the node numbers and their relationships for reference.  $R_2$  describes the conductance of the polyimide (epoxy) layers in each node. To calculate the resistances of  $R_1$  through  $R_4$  Equation 4.6 is used.

$$R = \frac{12 L_i}{k_i w_i (th_i)} \quad 4.6$$

where  $L$  is the length of the heat flow path,  $th$  is the thickness of the contact area,  $w$  is the width, and  $k$  is the thermal conductivity of the material. Each epoxy layer is 0.01933 inches thick: each copper layer is 0.00134 inches thick. Table 4 lists the resistances calculated by equation 4.6 for the network shown in Figure 7.  $R_A$  through  $R_E$  are the equivalent resistances as the network is calculated, beginning with resistance  $R_A$  and working to resistance  $R_E$ . A sample calculation is included for resistance A.

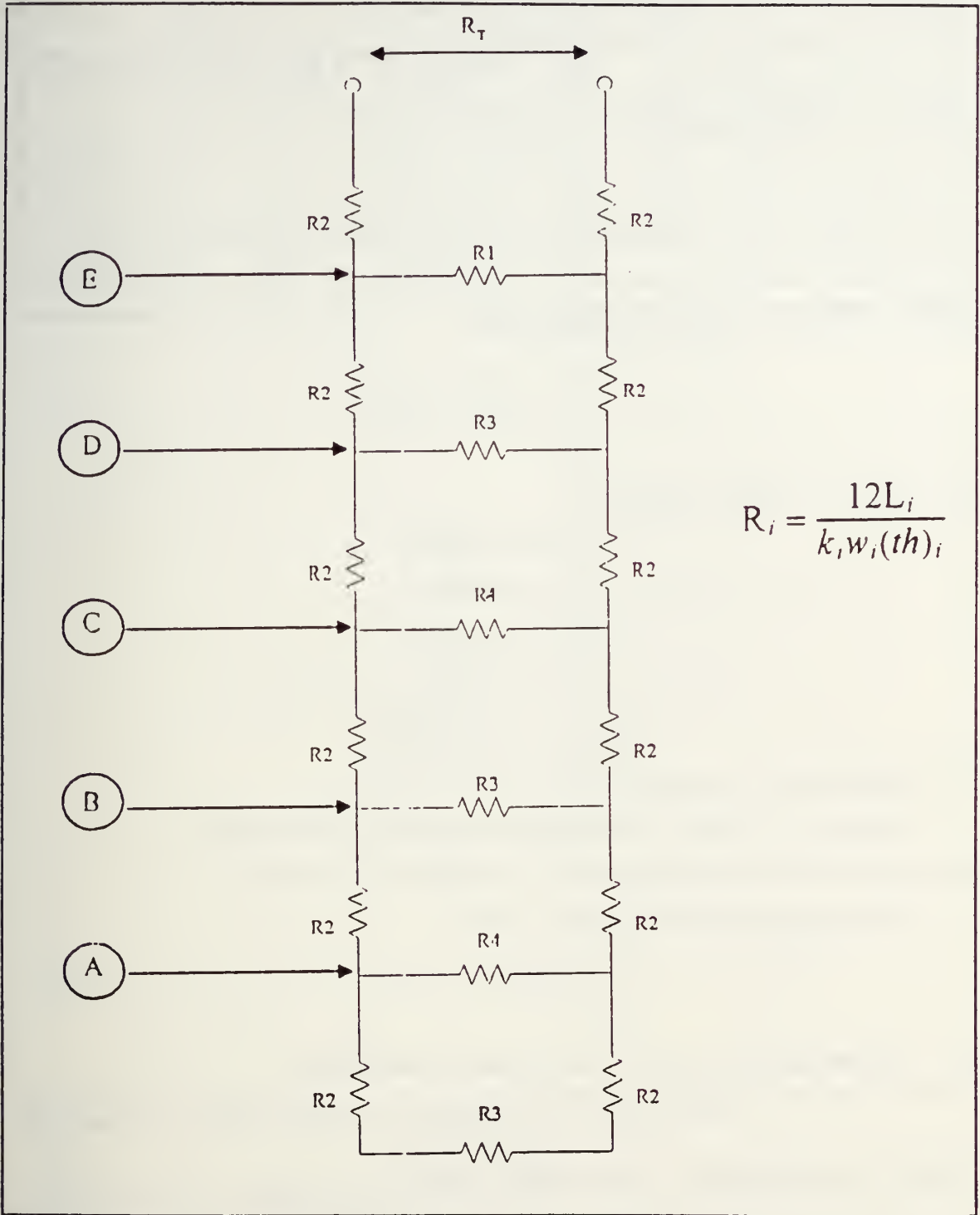


Figure 7. Electrical Power System Node 1 to Node 2

$R_i^{\#}$	$L_i$	$w_i$	$th_i$	$k_i$	$R_i$
1	1.00	1.00	0.00134	385 (.25)	93.04129
2	.01933/2	1.00	1.00	0.15	0.77320
3	1.00	1.00	0.01933	0.15	4138.645
4	1.00	1.00	0.00134	385	23.26032

Table 4. Node 1 to Node 2 Resistances

$$R_A = \frac{(R_3 + R_2 + R_2) R_4}{R_3 + R_4 + 2 R_2} \quad 4.7$$

As a result, for Node 1 to Node 2

$$R_A = 23.13037$$

$$R_B = 24.53051$$

$$R_C = 12.79438$$

$$R_D = 13.79438$$

$$R_E = R_T = 13.16939$$

Using Equation 4.1,  $K = 0.075934 \text{ } ^\circ\text{F-hr} / \text{Btu}$ .

The node 1 to node 9 calculations are based on the same relationships, so that conductance is  $0.075934 \text{ } ^\circ\text{F-hr} / \text{Btu}$ .

For the radiation from board to board

$$K = 0.1732 F_A F_E A \quad 4.8$$

$F_A = 1.00$  because the boards are parallel to each other.

$$F_E = \frac{1}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1} \quad 3.8$$

Because the emissivity of both boards is assumed to be 0.8,  $F_e = 0.6667$ .

After converting the node area into square feet

$$K = 0.1732 (1.0) \left(\frac{2}{3}\right) \left(\frac{1}{144}\right) = 0.801852 \times 10^{-3} \quad 4.9$$

Figure 8 describes the contact of the board layers to the housing rails.

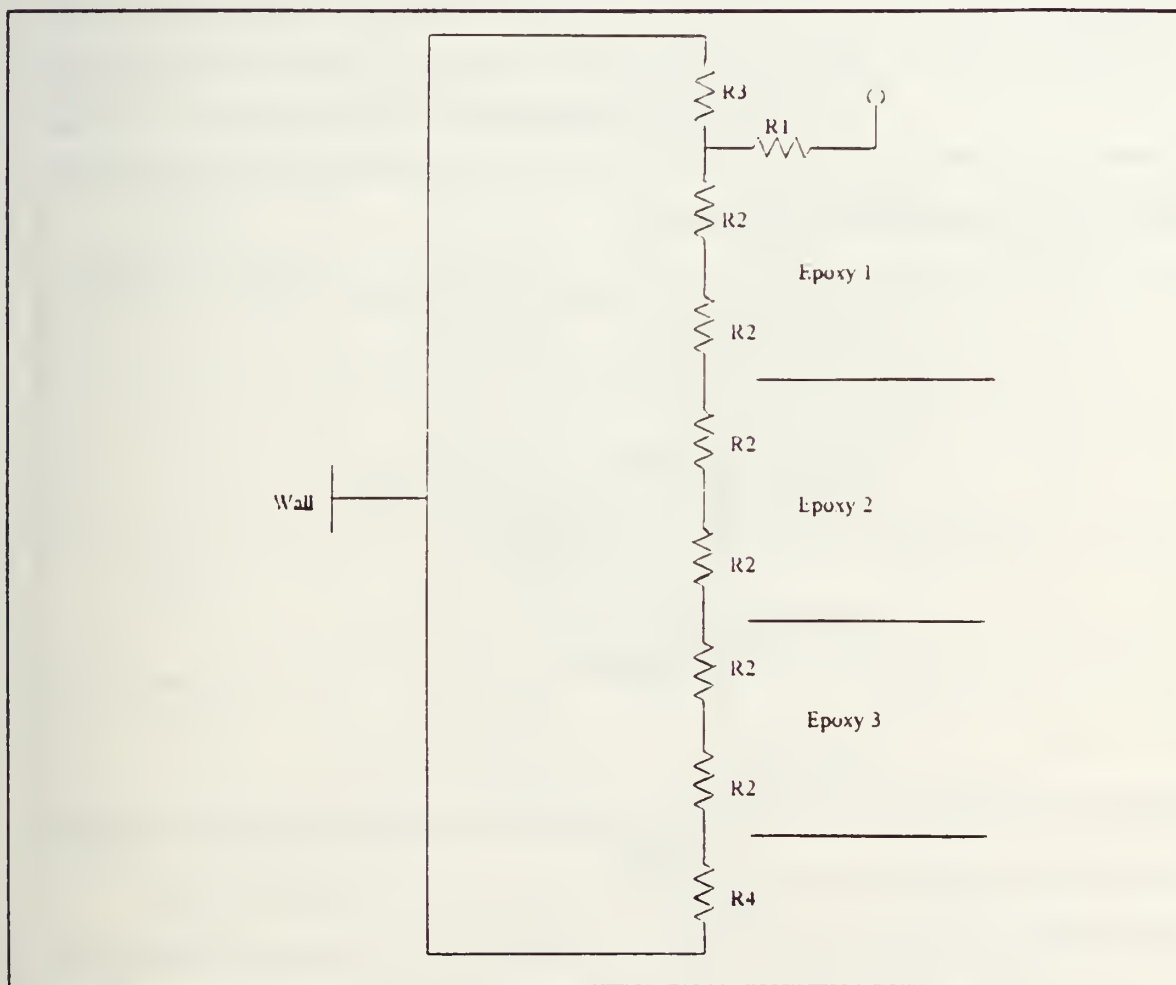


Figure 8. PCB Layers To Housing Conductances

Resistance  $R_1$  is copper and resistance  $R_2$  is epoxy. Resistances  $R_3$  and  $R_4$  are contacts with the railings.

$R_1$  is half that of the previous  $R_1$  ( the path length has been halved).



$$R_2 = \frac{(12) (0.01933/2)}{(1) (0.2) (0.15)} \quad 4.10$$

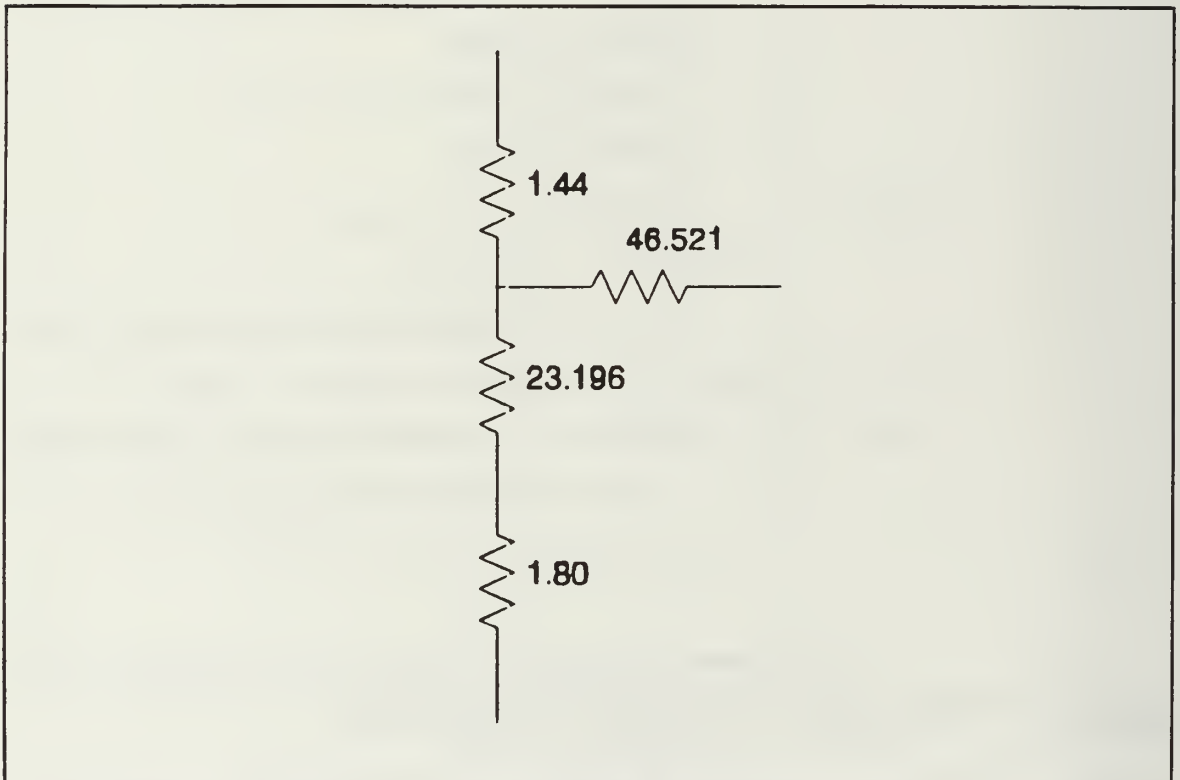
$h_c = 500$  for copper contact

$h_c = 400$  for epoxy contact

$$R_4 = \frac{1}{400 (0.2) (1/144)} = 1.88 \quad 4.11$$

$$R_3 = \frac{1}{500 (0.2) (1/144)} = 1.44 \quad 4.12$$

Figure 9 is a simplification of Figure 8.



**Figure 9.** Equivalent Conductance of Figure 8

The equivalent resistance from the network shown in Figure 9 ( $R_T$ ) = 47.88.  $K_T$  is the equivalent conductance, or 0.020885 ° F-hr/ Btu.

Once the conductances were calculated an input file was created, listing the conductances for each node with its associated mode. The input file is shown in Appendix D. The conductance values are listed by node. Beginning at lines 7 and 8 in Appendix D, the node equation describes what node is connected to what, by how much, and by which tag. At line seven, the fixed point integer values are connections and tags. Table 5 describes Node 1 connections contained in line 7.

NODE CONNECTION	POSITION	HOW	TAG
2	TOP PCB	CONDUCTION	1
9	TOP PCB	CONDUCTION	1
73	BOTTOM PCB	RADIATION	3
301	CONSTANT TEMPERATURE	CONDUCTION	1
303	CONSTANT TEMPERATURE	RADIATION	3

Table 5. Node Connections To Node 1

Line 8 contains floating point real numbers which are the appropriate conductance values for the connection. Each node requires an even number of lines. The three constant temperatures defined for the railings and housing were all 33.5 °C. Appendix E lists the heat dissipation by node in watts. The conductances need only be input in one direction as THANSS calculates the reverse connection automatically.

Table 6 lists the results of the steady state analysis of the circuit boards. The highest temperatures appeared on the bottom boards where the heat dissipations were the highest. However, the amount of dissipated heat is relatively low. Temperatures ranged from 34.42 °C to 36.31 °C on the upper board to 34.77 ° to 38.02 °C on the lower board, well within standard operating temperatures for electronic piece parts. A run at 25 °C constant heat source temperatures compared very favorably with an earlier steady state analysis performed using the Integrated Thermal Analysis System (ITAS).

PRINTED CIRCUIT BOARDS - S PATTERSON - RUN A												
Temperatures, degC												
1	35.38	2	35.78	3	35.96	4	35.92	5	35.80	6	35.67	
7	35.48	8	35.19	9	35.62	10	36.14	11	36.31	12	36.12	
13	35.88	14	35.72	15	35.54	16	35.34	17	35.56	18	36.00	
19	36.15	20	36.10	21	35.91	22	35.71	23	35.48	24	35.18	
25	35.65	26	36.16	27	36.24	28	36.25	29	35.95	30	35.64	
31	35.36	32	35.00	33	35.48	34	35.91	35	36.05	36	36.05	
37	36.07	38	35.56	39	35.24	40	34.90	41	35.55	42	35.96	
43	35.80	44	35.69	45	35.58	46	35.32	47	35.10	48	34.86	
49	35.36	50	35.60	51	35.65	52	35.42	53	35.27	54	35.08	
55	34.87	56	34.63	57	35.01	58	35.34	59	35.28	60	35.17	
61	35.06	62	34.91	63	34.72	64	34.49	65	34.80	66	35.03	
67	35.08	68	35.04	69	34.95	70	34.81	71	34.64	72	34.42	
73	35.53	74	36.12	75	36.49	76	36.67	77	36.91	78	37.19	
79	37.02	80	36.25	81	35.66	82	36.56	83	36.93	84	36.90	
85	37.20	86	38.02	87	37.99	88	36.51	89	35.63	90	36.28	
91	36.75	92	37.10	93	37.32	94	37.94	95	37.80	96	36.43	
97	35.63	98	36.23	99	36.82	100	37.78	101	37.44	102	37.35	
103	37.06	104	36.08	105	35.46	106	36.01	107	36.63	108	37.69	
109	37.25	110	36.91	111	36.50	112	35.74	113	35.43	114	35.90	
115	36.26	116	36.54	117	36.55	118	36.43	119	36.15	120	35.46	
121	35.11	122	35.60	123	35.75	124	35.91	125	36.05	126	36.03	
127	35.83	128	35.23	129	34.85	130	35.18	131	35.38	132	35.53	
133	35.68	134	35.70	135	35.55	136	35.02	137	34.71	138	34.99	
139	35.19	140	35.32	141	35.41	142	35.38	143	35.21	144	34.86	
301	33.50	302	33.50	303	33.50							

Figure 10. PANSAT PCB Temperature by Node

## V. TRANSIENT ANALYSIS OF EPS USING ITAS

### A. GEOMETRY GENERATION

To begin the analysis of the electrical power system, the geometry of the EPS was reproduced in the computer using the Integrated Thermal Analysis System (ITAS). The geometry was generated by piecing together, rotating and translating shapes from a geometry generation menu. These shapes were then stored in a PARTS file, which were then selectively plotted to allow for surface number and node number displays. The EPS was divided into three distinctly separate entities: the housing and the upper and lower circuit boards. Figure 10 and Figure 11 show the surface numbers and corresponding node numbers for the EPS housing. Each surface generated by ITAS is accessible for thermal node definitions and optical

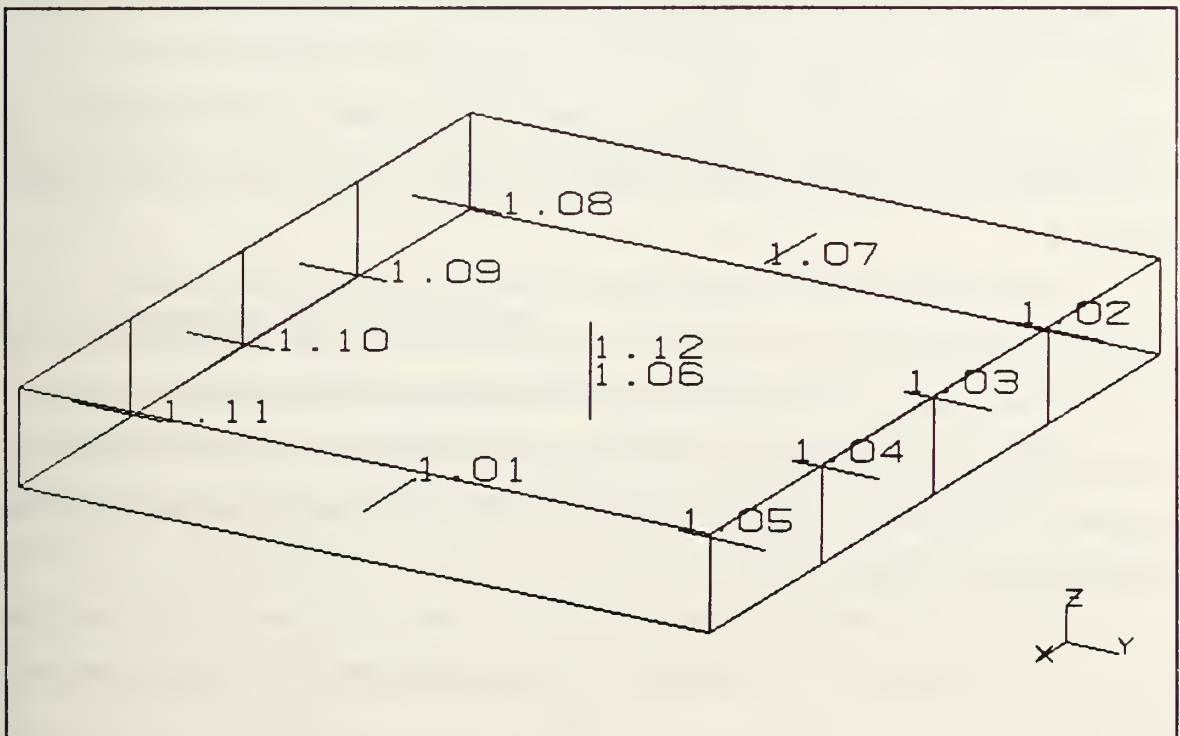
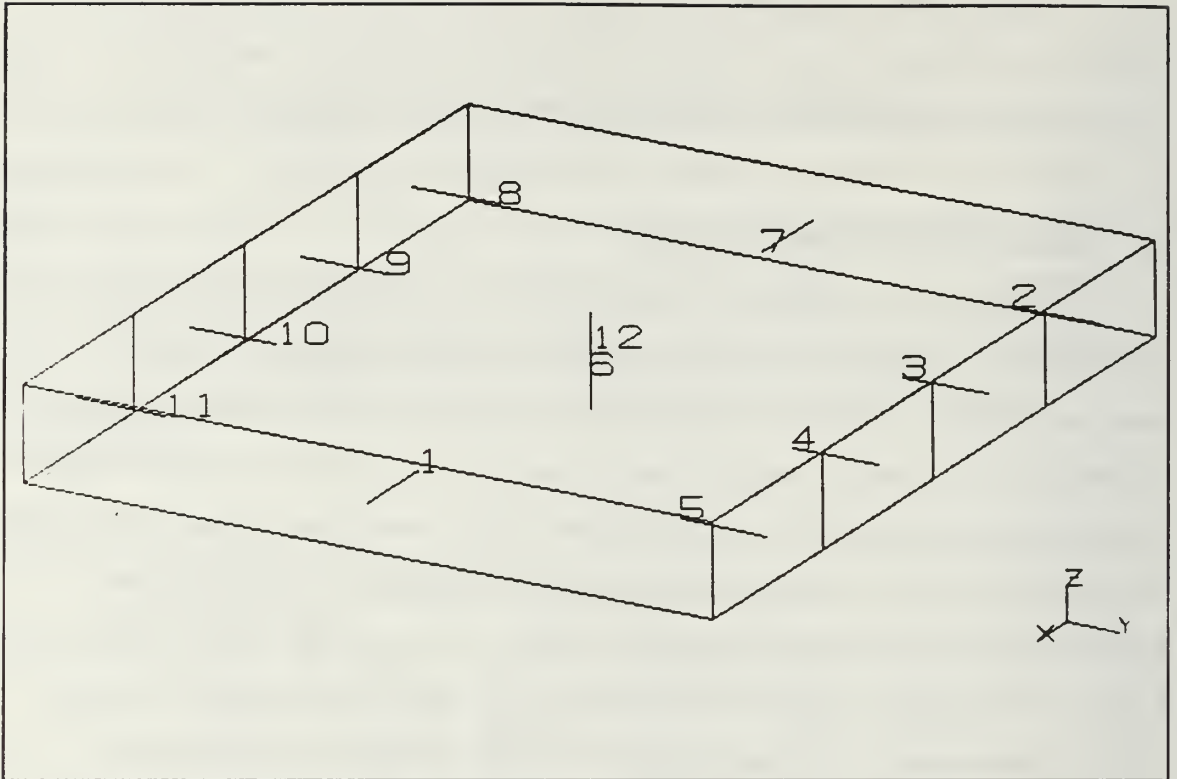


Figure 10. EPS Housing Surface Nodes



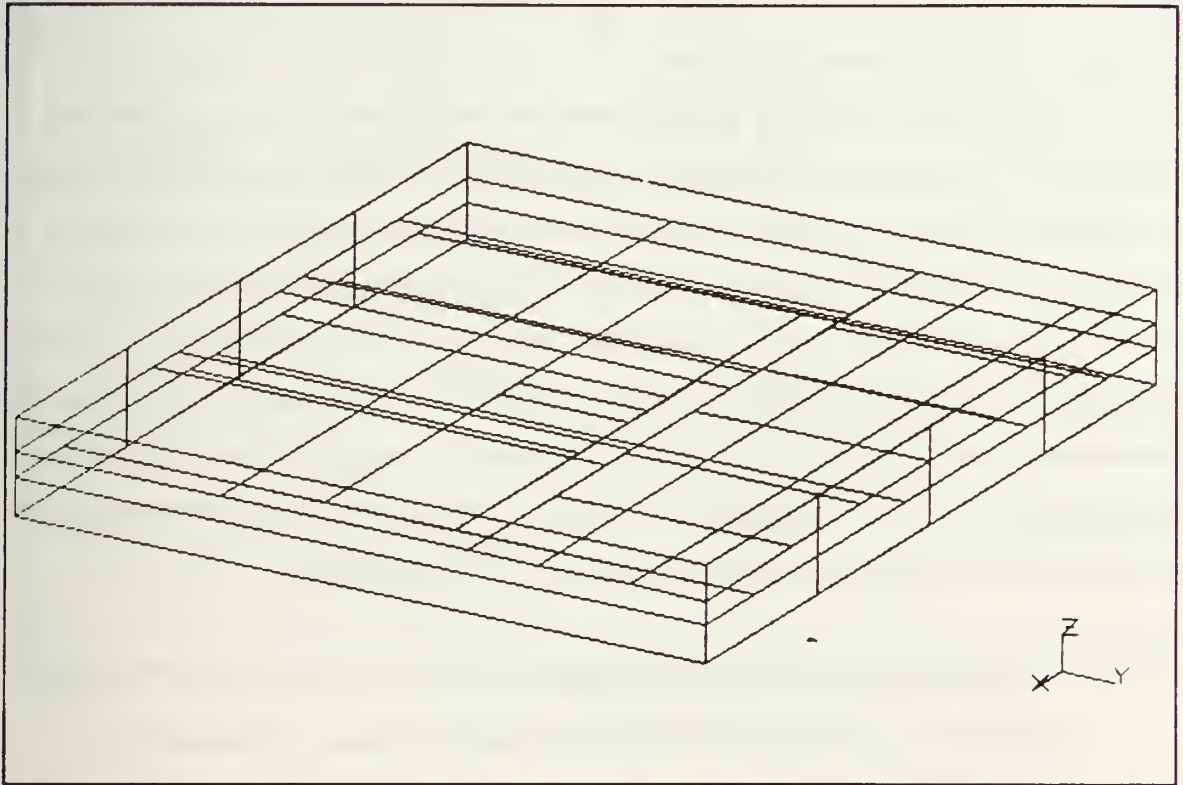
**Figure 11.** EPS Housing Node Numbers

properties definition. The housing is modelled as a six-sided box having 12 physical nodes. The dimensions of the housing are 9 inches in the X direction, 8 inches in the Y direction, and 1.569 inches in the Z direction. It is mounted underneath the upper equipment plate as seen in Figure 2 and Figure 3.

The upper printed circuit board is modelled as two four sided polygons. The polygons have node numbers from 2.01 to 2.18 and 3.01 to 3.12. This division of the upper equipment panel was done to accurately represent heat dissipations on the board and to define a workable number of conductance values. Appendix F shows both the surface numbers and node numbers for the upper PCB.



The lower PCB was constructed from 5 separate polygons: these node numbers ranged from 4.00 to 8.00. Appendix G shows the surface numbers and corresponding node numbers for the lower PCB. Figure 12 is a view of the integrated thermal nodes of both PCBs and the housing.



**Figure 12.** Geometry Model of the Electrical Power System

## **B. THERMAL PARAMETERS**

### **1. Radiation Conductance Parameters (Script-F)**

Script-F factors are the energy quantities incident on each of the surfaces of an enclosure after multiple reflections from the surrounding surfaces. (ITAS User's Manual). The Script Fs are in the IR wavelength and are used during the thermal analysis to account for all thermal radiation interchange, and are calculated from the blackbody view factors in



conjunction with surface optical properties. Since the EPS is an enclosure with no view to space, the program is set to ignore the space node inclusion in the Script F calculations since surfaces inside the enclosures do not "see" surfaces outside the enclosure. [ITAS User's Manual, 1992]

## **2. Optical Properties Data**

The optical properties data defines the properties of all surfaces and combines the geometric surfaces that have been created into thermal nodes. The optical properties listed in the Material Properties Library of ITAS were used for the housing (Aluminum 6061-T6) and for the copper layers of the printed circuit boards. These properties include the solar absorptivity ( $\alpha$ ) and infrared emissivity ( $\epsilon$ ) values. Individual capacitances and thermal dissipations were not defined in these screens but were defined in the User Node section. The surfaces that are listed in the Optical Properties entries in Appendix H are the geometric surfaces that ITAS generates.

## **3. Non-Geometric Node Definitions**

In addition to the Optical Property node generation, additional non-geometric nodes were created. These nodes do not have a physical presence in ITAS. Examples of these nodes included the rails in the EPS housing to which the circuit boards are secured; the PCB board layers, which alternate copper and polyimide; the upper equipment plate, to which the top of the EPS is mounted; and the component pin nodes. Table 6 indicates the non-geometric node assignments. These nodes are also known as diffusion nodes: diffusion nodes, although not part of the ITAS geometry file still have finite mass. Nodes are not numbered consecutively to allow for flexibility and also to allow easy identification. For example, all nodes that are numbered 9XX are either housing or railing nodes: all of these nodes are

made of aluminum. Nodes 16XX and 6XX, 14XX and 4XX, 12XX and 2XX are all copper layers of the printed circuit boards.

Node Number	Identification	Node Number	Identification
901-912	EPS housing	913	Equipment Plate
921-926	EPS rails	201-230	Top PCB top Cu
401-430	Top PCB mid Cu	<del>501-530</del>	Top PCB bot Cu
1201-1217	Bot PCB top Cu	1401-1417	Bot PCB mid Cu
1601-1617	Bot PCB bot Cu	101-130	Top PCB T poly
301-330	Top PCB M poly	501-530	Top PCB B poly
1101-1117	Bot PCB T poly	1301-1317	Bot PCB M poly
1501-1517	Bot PCB B poly	2XXX	Pins-Top PCB
3XXX	Pins- Bot PCB		

Table 6. Non-Geometric Node Numbers

The thermal capacitance of the diffusion nodes is entered in this screen. Thermal mass is also another name for thermal capacitance.

$$\text{Thermal Mass} = C = c \rho V \quad 5.1$$

where  $c$  is specific heat in cal/g °C,

$\rho$  = density of the material in kg/m<sup>3</sup>,

$V$  = volume of the material in m<sup>3</sup>.

ITAS requires C to be in W-min / °C. To convert to the correct units the following conversion factor is used.

$$C = \left( \frac{\text{cal}}{\text{g}^{\circ}\text{C}} \right) \left( \frac{\text{kg}}{\text{m}^3} \right) (\text{m}^3) = \frac{\text{cal}}{(.001)^{\circ}\text{C}} \quad 5.2$$

$$1 \text{ cal} = 1.163 \times 10^{-6} \text{ kw-hr} = 1163 \times 10^{-6} \text{ W-hr} \quad 5.3$$

$$1163 \times 10^{-6} \text{ W-hr} = 6.978 \times 10^{-2} \text{ W-min} \quad 5.4$$

$$\frac{6.978 \times 10^{-2} \text{ W-min}}{(0.001)^{\circ}\text{C}} = 69.78 \text{ W-min}/^{\circ}\text{C} \quad 5.5$$

This is the conversion factor used in Appendix I to calculate the thermal masses of all physical nodes. The following values were used in the calculations. [Penton Publishers, 1986]

EPS Housing Thickness	0.2 in
Equipment Plate Thickness	0.125 in
PCB Board Copper Layer	0.000134 in
PCB Board Poly Layer	0.001933
Density of Aluminum	2728 kg/m <sup>3</sup>
Density of Polyimide	1950 kg/m <sup>3</sup>
Density of Pin Material	8378 kg/m <sup>3</sup>
Density of Copper	8666 kg/m <sup>3</sup>
Specific Heat of Al	0.199 cal/kg °C
Specific Heat of Cu	0.098 cal/kg °C
Specific heat of Ni-Steel	0.11 cal/kg °C
Specific Heat of Polyimide	0.31 cal/kg °C

Since ITAS allows total capacitance of each surface of the nodes to be entered into the model if the remaining surfaces are zeroed out. For pin

conductances, the total thermal mass of the pins in each major node were considered as one node. For example, Node 2011 is the total capacitance of all pins through the top layer of geometric node 3.01.

Heat dissipations were also entered in this screen. These dissipations were obtained from the PANSAT design team. The component list and PCB board layouts are included as Appendix J. The top board design is currently much more mature than the lower board design and estimated heat dissipations were more accurate. Appendix K is the Node Data Entry for Thermal Analysis for the EPS.

**4. Conductance Definitions**

All conductances entered into the EPS model were defined as linear (two way); this type of conductance also applies to the nodes defined by ITAS. All conductance values were precalculated and entered into the model: unlike THANSS, radiation modes are calculated by ITAS. Equation 3.3 was used to calculate all conductances not involving contact conductances.

$$K = \frac{k A}{L} \tag{3.3}$$

Conductances not involving contact conductances included EPS housing to housing nodes; EPS housing to railing nodes (since the rails will be part of the housing); copper board nodes to copper board nodes and polyimide to polyimide nodes; and pin segment nodes to pin segments. Pins were modeled as one equivalent pin through each geometric node; however, each pin was divided into six nodes since they traverse through the board layers.

## 5. Contact Conductances

Contact conductance is defined in Equation 5.6.

$$h_c = \frac{(1.25) (k_s) \left(\frac{P}{H}\right)^{.95}}{S_r} \quad 5.6$$

$$k_s = \frac{2 k_1 k_2}{k_1 + k_2} \quad 5.7$$

where  $P$  = contact pressure of the surfaces, chosen as 15 psi for all contact.

$H$  = hardness of the material. Brinell hardness numbers were used.

$S_r$  = surface roughness

To calculate total conductance, first the conductance of the first material is calculated using Equation 3.3, resulting in  $K_1$ . Then the conductance of the second material is calculated, resulting in  $K_2$ . The total conductance ( $K_T$ ) is calculated by Equation 5.8, with the results in  $W / ^\circ C$ .

$$K_T = \frac{1}{\frac{1}{K_1} + \frac{1}{h_c} + \frac{1}{K_2}} \quad 5.8$$

The ITAS node-to-node conductance calculations are shown in Appendix L, with the conductance data entry in Appendix M.

## 6. Temperature Profile

ITAS uses temperature profiles for time varying boundary nodes. Boundary nodes without time variation must be input into the user-node definition section. A temperature profile (Figure 13) of the upper equipment



plate obtained from the THANSS/TASS transient analysis of the spacecraft structure used in the EPS analysis. The initial temperature was an estimate of Kennedy Space Center temperatures in October.

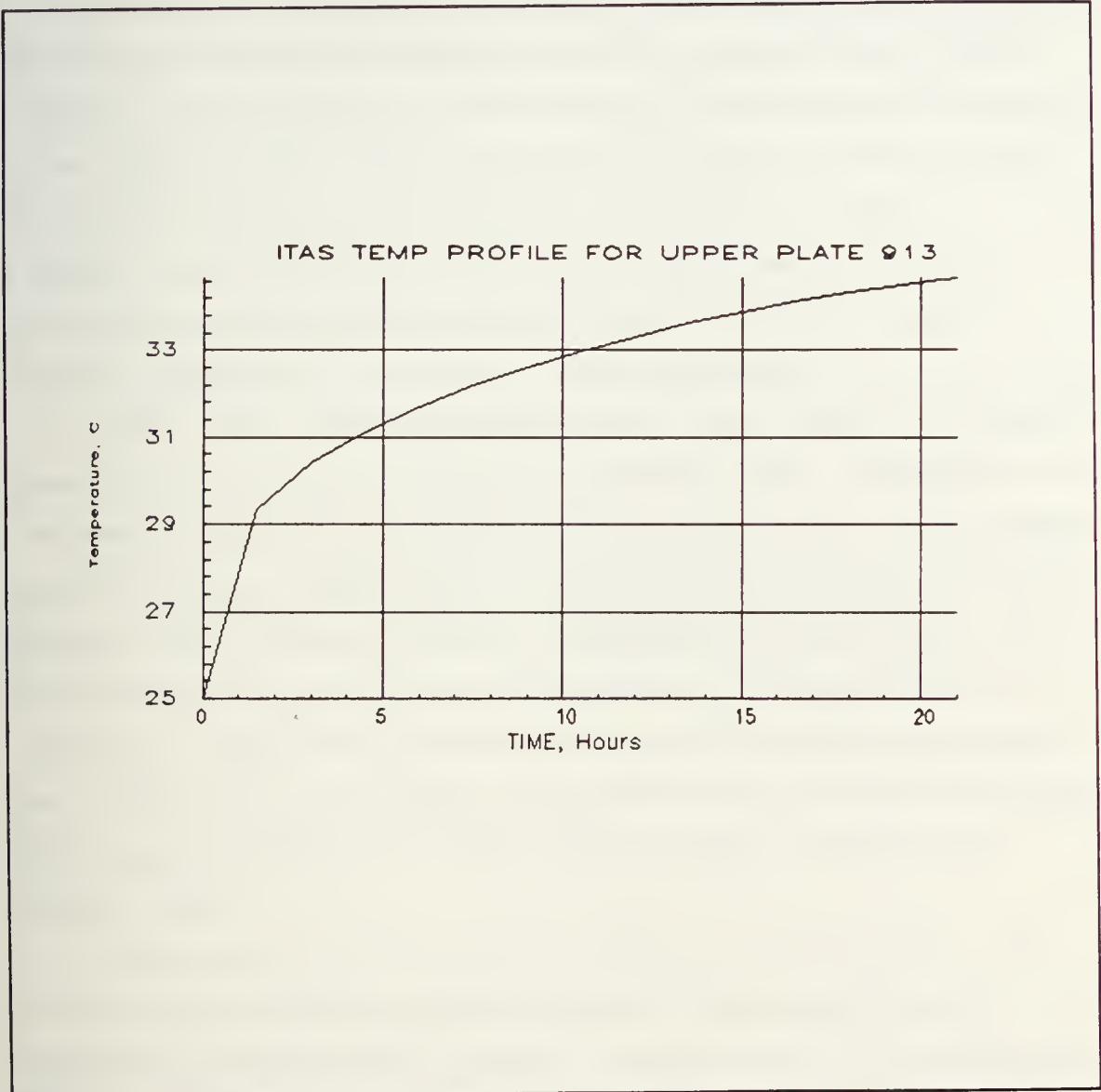


Figure 13. ITAS Temperature Profile For Equipment Plate





## **VI. THERMAL ANALYSIS OF BATTERIES**

### **A. NICKEL-CADMIUM BATTERIES**

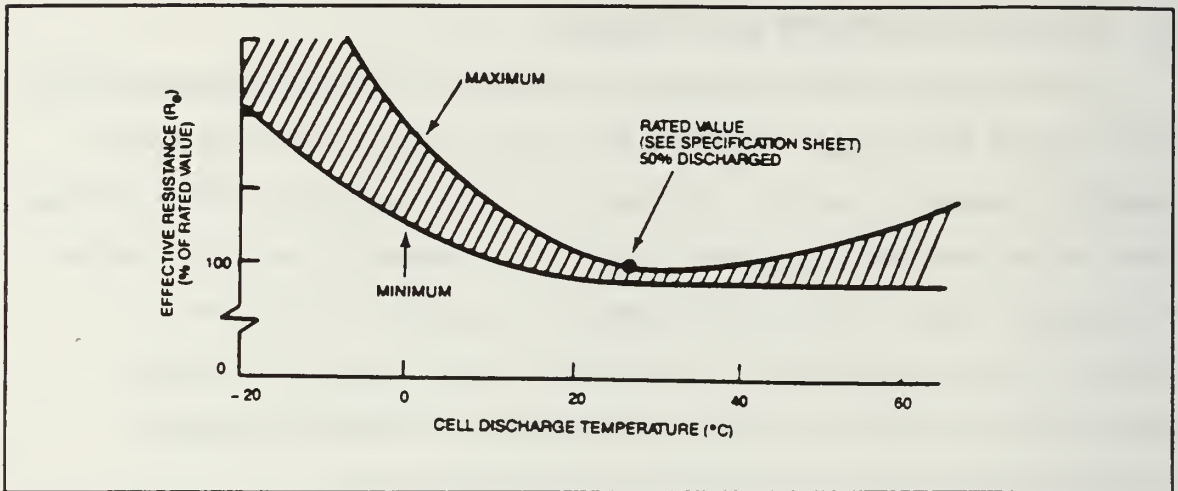
Batteries can either be primary or secondary; secondary batteries can be recharged and reused. Batteries are made of cells that can be linked together in series or parallel. Cells linked in series have the positive terminal linked to the next cell's negative terminal: in a parallel connection positive terminals are linked to positive terminals and negative to negative.

PANSAT's two batteries have 10 cells each linked in series. In series connections the voltage of the connected cells add while the capacity (normally measured in ampere hours) remains constant.

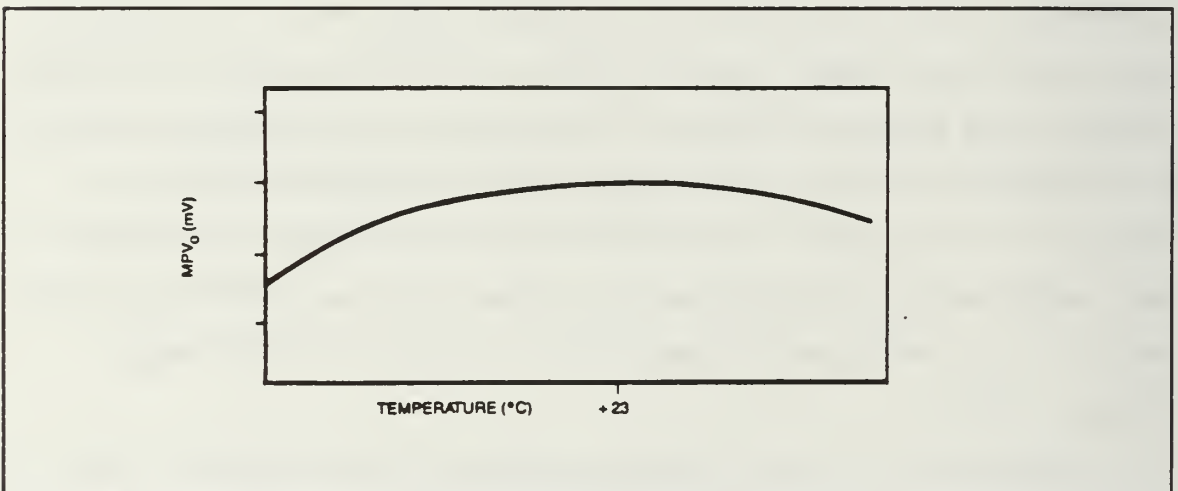
Sealed nickel cadmium cells operate as a closed system that recycle gases created within the cell, so that no electrolyte is lost. Sealed cells with a resealable vent for safety are still considered sealed cells. Nickel-cadmium cells (Ni-Cd) have a higher energy to volume ratio than most other secondary batteries, have a relatively high rate of discharge, and can recharge quickly. Ni-Cd batteries are known for their long storage and operating life, can operate over a wide range of temperatures and environments maintenance free. Additionally, Ni-Cd batteries can handle continuous overcharge so the battery can be maintained in a ready state until needed. [Gates Energy Products, 1992]

Temperature is a very important condition for Ni-Cd batteries. The effective internal resistance of these cells is at a minimum when cell temperature is between 20 °C and 40 °C. Figure 14 shows the relationship between cell discharge temperature and the effective internal resistance. Temperature also effects a cell's effective no-load voltage. For an Ni-Cd

cell, the effective no-load voltage is near the peak at room temperature: the decline is more pronounced at cooler temperatures. Figure 15 shows the



**Figure 14.** Cell Discharge Temp vs Internal Resistance  
"From Ref. [Gates, 1992]".



**Figure 15.** Cell Discharge Temperature vs No-Load Voltage  
"From Ref. [Gates, 1992]".

relationship between cell discharge temperature and no-load voltage.

An increase in cell temperature also has a negative effect on cell capacity. At elevated temperatures more charge is required for the cell to

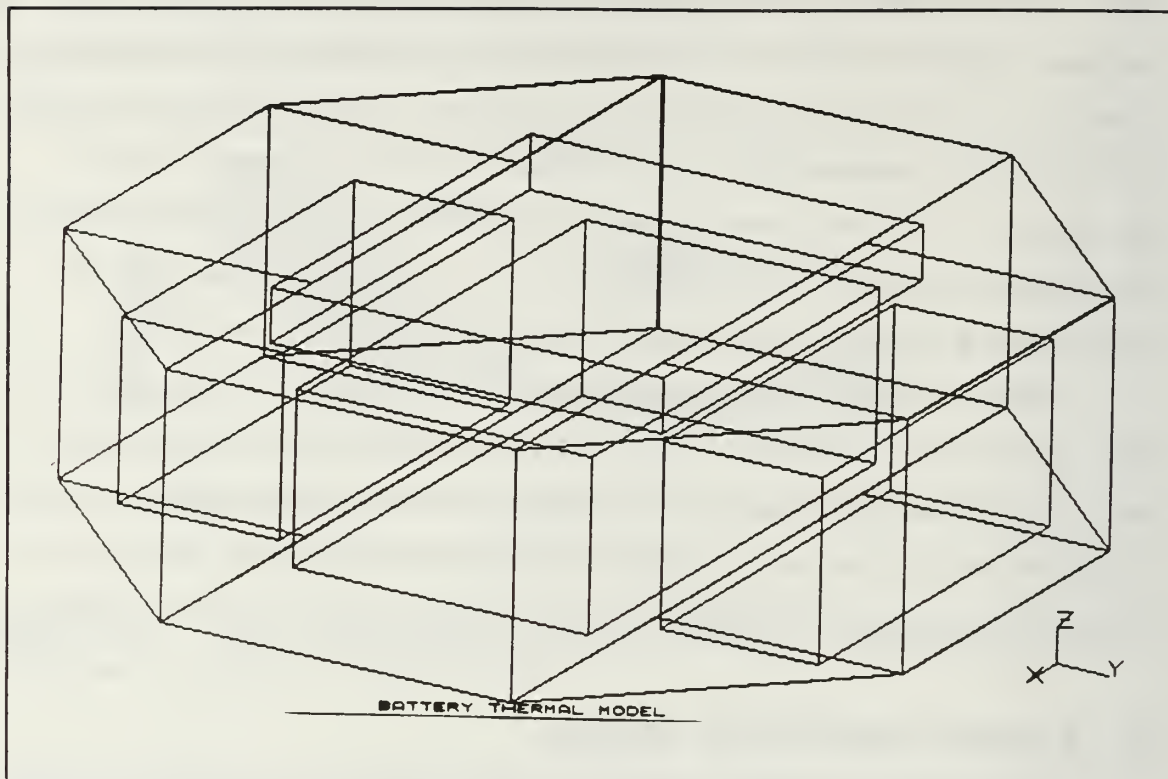
become fully charged, and the higher temperatures also decrease the cell capacity to below standard. Cell capacity while charging is not normally affected by temperatures below 23 °C, however, lower temperatures (below 23 °C) have a negative effect on cell capacity during discharge. Room temperature is the ideal environment for PANSAT's batteries. Space rated Ni-Cd batteries would be the technical choice for PANSAT; however, the cost of space rated batteries (approximately \$200,000) is prohibitive.

PANSAT batteries are redundant: only one battery will operate at a time. However, the batteries must recharge to full capacity between each use for optimum performance. The current power budget is being examined to determine how long each battery will take to recharge after each use. A typical Ni-Cd battery will require about 160% of energy stored to recharge.

## **B. BATTERY GEOMETRY MODEL**

To model the PANSAT battery, it was necessary to include the Digital Control Subsystem and the Electrical Power Subsystem in the model due to the proximity in the spacecraft. The model was built using ITAS. The two batteries and the DCS were the mounted on the lower equipment plate, built by connecting seven polygons. The spacecraft structure was built around the lower equipment plate, and the upper equipment plate, with the Electrical Power Subsystem (EPS) attached was added. The build progression is demonstrated in Appendix N. The geometric battery thermal model is shown in Figure 16.

After building the geometry model each surface was assigned a surface number and a node number. An example of this assignment is shown in Appendix O. The surface number and node number are related in the property data information of the model, shown in Appendix P. This is where the absorptivities and emissivities of the structure and box housings



**Figure 16.** Battery Thermal Model

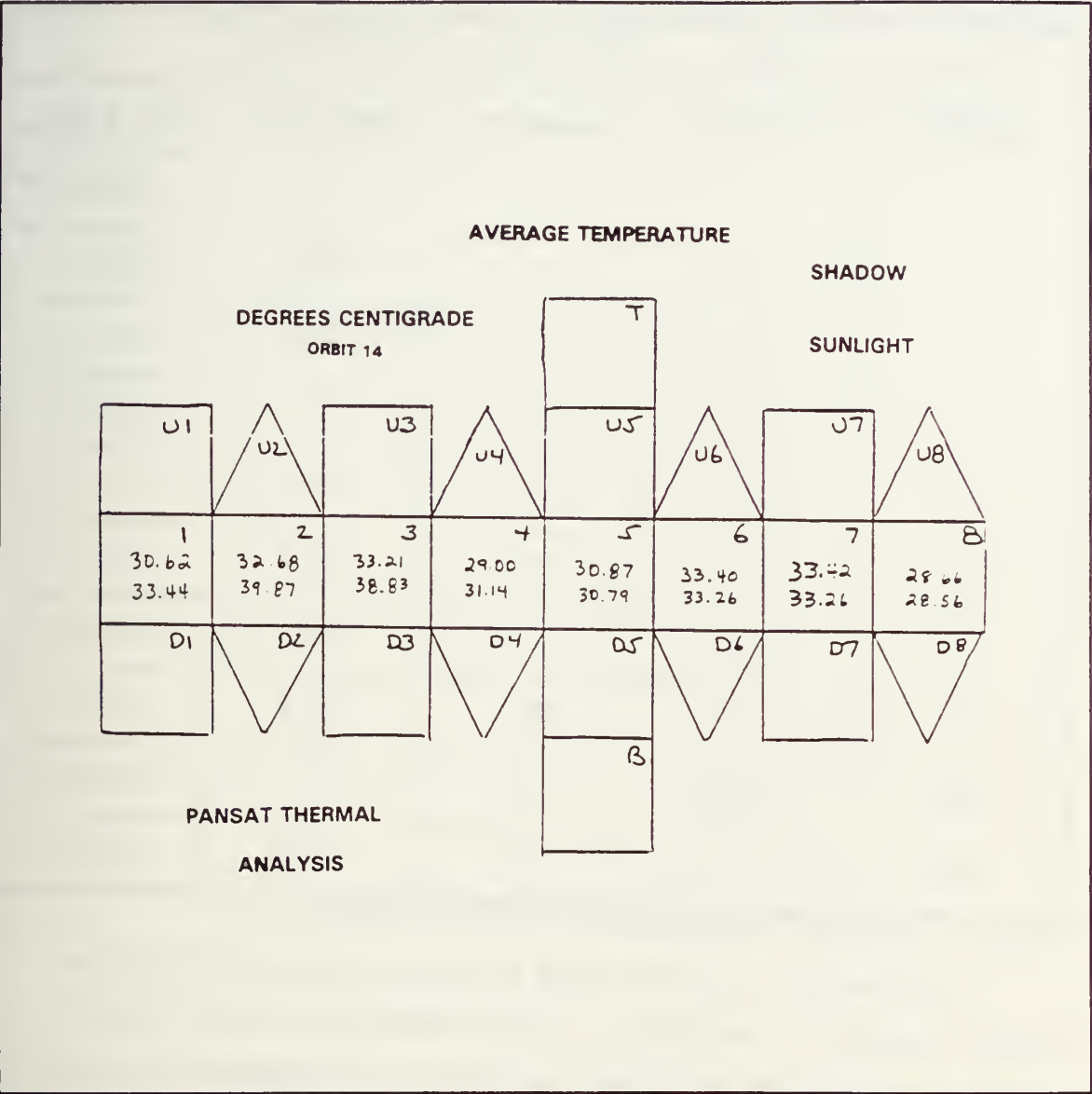
are listed. Since the box housing designs are not finalized, Aluminum- 6061-T6 was chosen. This material has an absorptivity of 0.4 and an emissivity of 0.79. Additionally, every surface on the boxes is given its own surface number and node number.

### **C. BOUNDARY CONDITIONS**

Since a large percent of the model required the incorporation of PANSAT's structure, boundary nodes were used to define temperatures on areas that had already been analyzed. Surfaces that were defined as boundary nodes have temperatures which remain constant. The results from the transient analysis of PANSAT's structure were used. The structure was divided into areas as seen in Figure 17. Each square area is divided into nine



equal nodes: the triangular areas are divided into six unequal nodes. The sections affecting the battery model are sections one through eight.



**Figure 17.** PANSAT Structural Divisions

Appendix Q lists the transient temperatures with internal heat dissipation by node for the shadow and sunlit zones for orbit 14. This was chosen since the spacecraft temperatures are leveling out: however, worst case



temperatures were not extrapolated. Table 7 relates the structural number of Figure 17 to the node numbers of Appendix Q, and then lists the average temperature for that area for both shadow and sunlight.

	NODE	AVG. TEMP	AVG. TEMP	
SECTION	NUMBERS	SHADOW	SUNLIGHT	S/C AREA
1	1-9	30.6	33.4	WALL
2	10-18	32.7	39.9	WALL
3	19-27	33.2	38.8	WALL
4	28-36	28.7	31.1	WALL
5	37-45	30.8	30.9	WALL
6	46-54	33.4	33.3	WALL
7	55-63	33.4	33.3	WALL
8	64-72	28.7	28.6	WALL
N/A	219-226	32.9	33.7	LOWER PL
N/A	211-218	32.1	32.9	UPPER PL

Table 7. Average Temperatures in Celcius for Pass 14

These temperatures were used as boundary nodes, indicated as negative numbers in Appendix R. This appendix also lists the thermal masses (capacitances) for all hardware nodes. The explanation for thermal mass calculation is contained in Chapter V; the thermal mass calculations are included as Appendix S. Heat inputs to each box were estimated and defined in Appendix R as a node with no mass. This heat input was attached to the six walls of the housing where that heat input resides, and

the heat was conducted outward through the walls. EPS boundary conditions were derived from the transient analysis.

Conductance values were calculated as in Chapter V and included in the ITAS Conductor Data Entry. Only surfaces within the boxes themselves or conductances between the heat nodes and the boxes are included since the upper plate, lower plate, and sidewalls are defined to have constant temperatures.



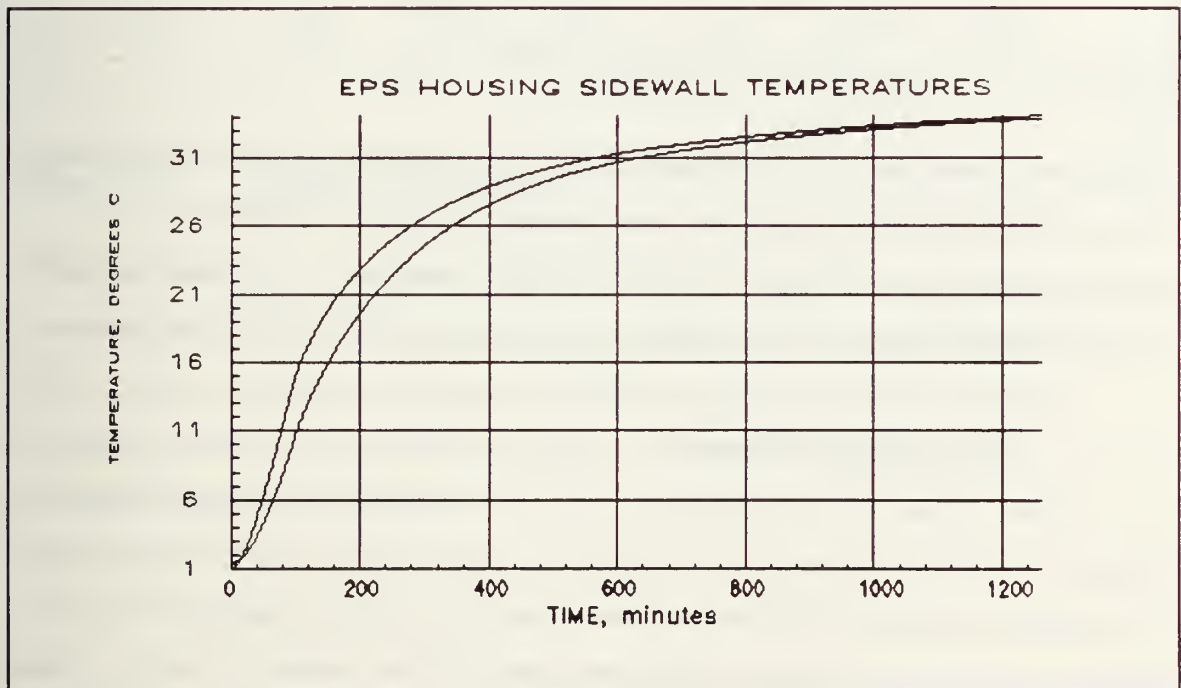
## VII. RESULTS AND RECOMMENDATIONS

### A. ELECTRICAL POWER SYSTEM

The analysis of the EPS transient analysis can be divided into three areas; the housing nodes, the upper board nodes, and the lower board nodes.

#### 1. EPS Housing Nodes

Figures 18 and 19 show the temperature versus time plots for the EPS housing sidewalls and the top and bottom of the housing. As it would be expected for a node which touches the outside edges of the housing, the



**Figure 18.** EPS Housing Temperature Trends

temperatures start low and become warmer. The bottom plate in the EPS housing would tend to be warmer than the top because the bottom has

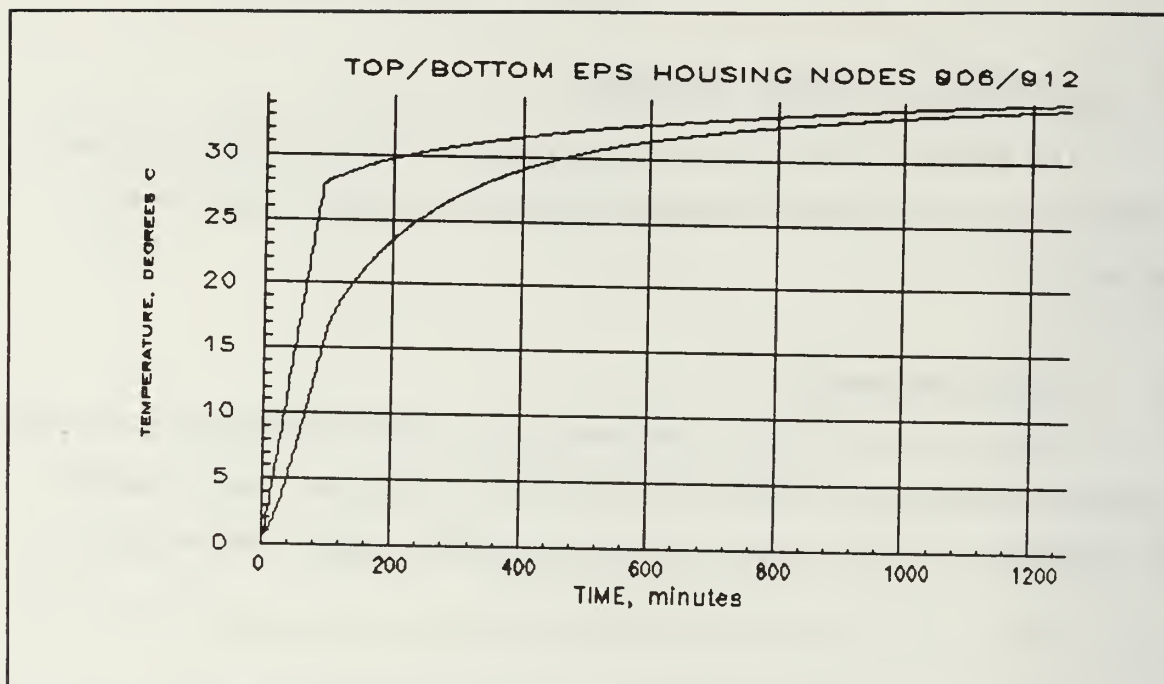
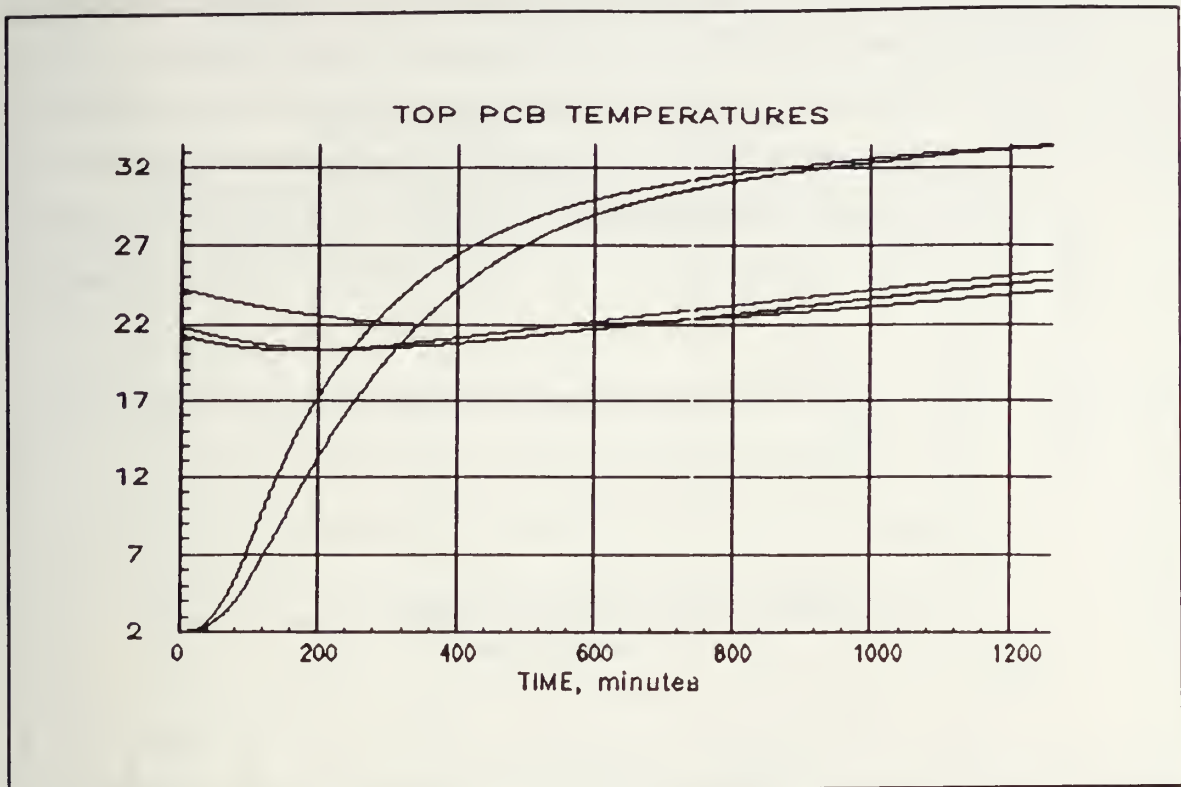


Figure 19. EPS Housing Trends

more heat dissipation. One drawback to the present analysis is that there was only enough information for a temperature profile of the lower equipment plate for 14 orbits. This, in effect, results in a transient analysis for that period of time and a steady state analysis for the following time.

## 2. Printed Circuit Boards

From Figure 20 it is apparent that any node that is attached to the housing sidewalls is going to experience a trend similar to the housing itself. In the case of the top PCB, nodes which butt up to the housing start cold and see a decreasing slope, starting to level off after about 17 hours. Nodes that do not touch the sidewalls (midboard in this case) remain between 20°C to 25 °C for the duration. This board remains cooler than the bottom PCB because the heat dissipations in the upper board are relatively low.



**Figure 20.** Upper PCB Results

The bottom PCB, as shown in Figure 21, has a similar curve for those nodes which attach to the rails, with the resulting final temperature very similar to the upper PCB. However, midboard nodes are approximately 4-5 degrees warmer on the bottom board, where the highest heat dissipations are concentrated.



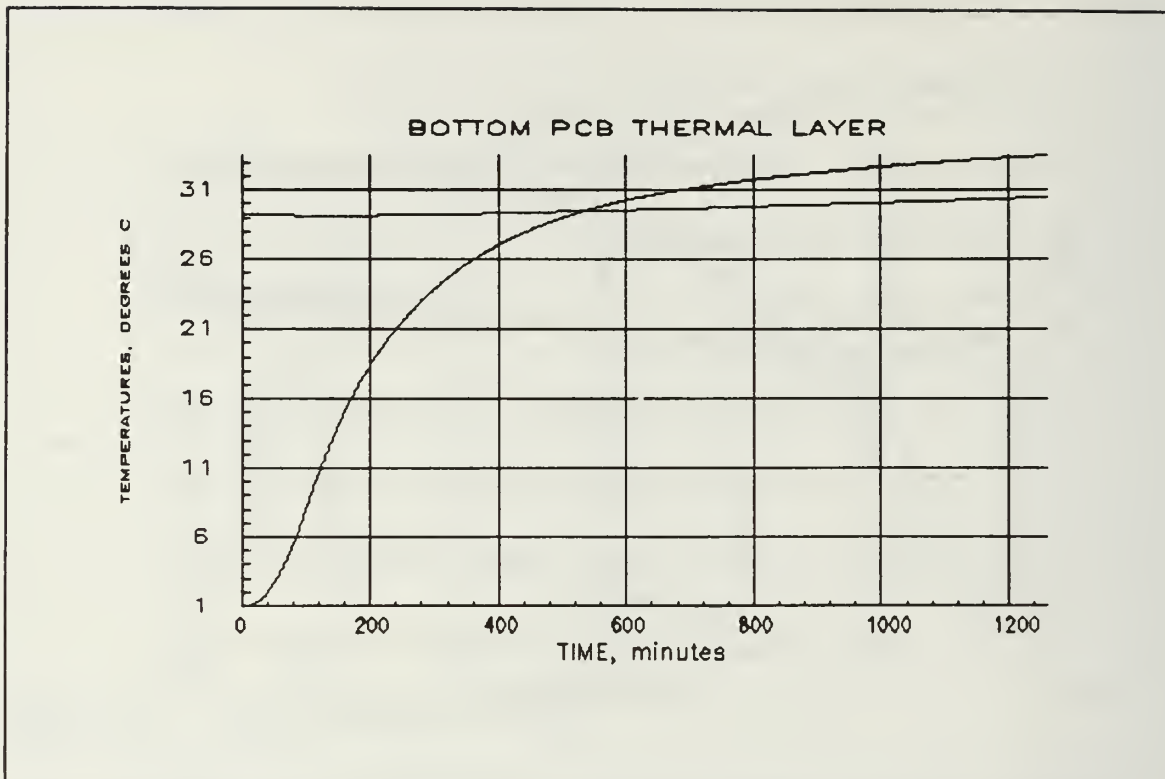


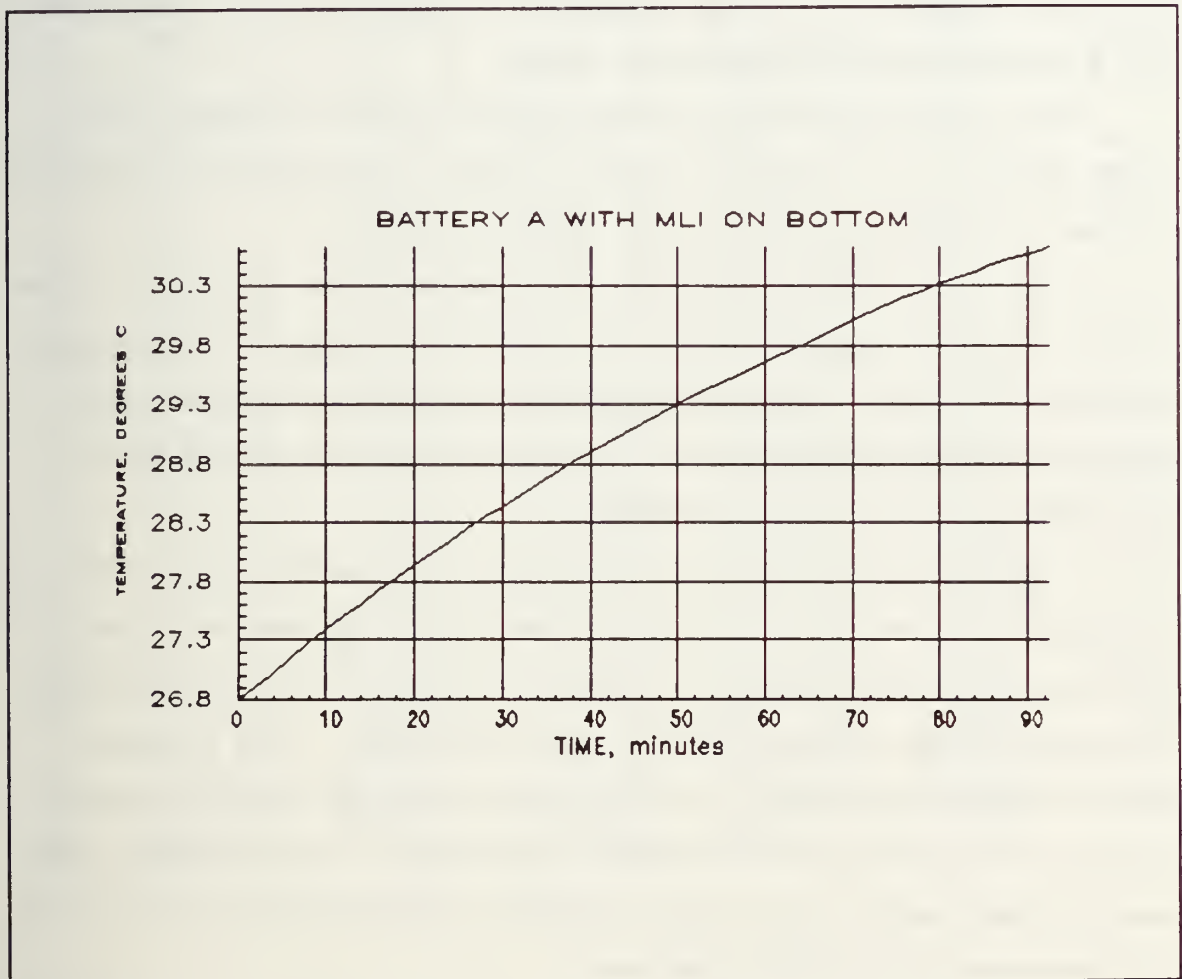
Figure 21. Bottom PCB Trends

## B. BATTERIES

A steady state analysis was performed first on the battery. A copy of the results of both the steady state and the transient analysis is included as Appendix V. The transient analysis shows Battery A, Battery B, and the DCS at 33.7 ° C.

ITAS would not allow the model to be run as an enclosure. An ideal case would have been to run the battery first as an enclosure similar to the procedure used for the EPS. Since the cell information was not available, this run was performed to give a general battery environmental range. The analysis was effectively a steady state analysis since most of the structure had boundary nodes attached. This temperature is within the advertised

advertised operating ranges for a battery but is some distance from the ideal 23 °C. A second analysis was performed simulating a layer of Multilayer Insulation (MLI) on the bottom of both batteries. The result of this analysis can be seen from Figure 22. Although the initial temperatures are lower, the boxes quickly heat up. A third run insulating all six sides reduced the temperature by 3 °C to 30.7 °C.



**Figure 22.** Temperature vs Time for Battery with MLI

## **C. RECOMMENDATIONS**

To make the thermal analysis more realistic for the Electrical Power System, duty cycles for the printed circuit boards need to be established. This would give a more accurate time versus temperature plot. For the batteries, cell selection would allow the modelling of the cells inside the batteries as demonstrated in Appendix W. Dissipations for the high power use boxes would contribute to the accuracy of the model. As the individual boxes are created by ITAS, the spacecraft subsystems can be combined into a viable and accurate spacecraft model.

This analysis is only as accurate as the boundary conditions. This model should be rerun when boundary conditions obtained from the transient analysis of PANSAT structure using ITAS are completed.

ITAS was created to model spinning and stationary spacecraft. When PANSAT design is mature enough to run the entire model, there is an option in the Parameter Set Up and Alteration Menu for user defined spacecraft attitudes, where the satellite can be rotated in time on the X-Y-Z axes to more accurately represent a tumbling body.

ITAS can accurately represent the orbit of the satellite, and allows two methods. The first method requires the definition of the inclination, sun Right Ascension and Declination, and the Longitude of the Ascending Node. The other method requires definition of the beta angles. Both methods define perigee and apogee, so that time spent in sunlight and time spent in shadow are considered in the satellite's environment. The most likely orbit, looking ahead with shuttle mission manifests, suggests planning for a  $51.6^\circ$  inclination and a 213 NM circular orbit.

# APPENDIX A. PANSAT STEADY STATE TEMPS IN SUNLIGHT

Page No. 1

PANSAT - STEADY STATE - SUNLIGHT ZONE - WITH INTERNAL HEAT DISSIPATION  
Temperatures, degC

1	54.98	2	57.32	3	59.02	4	53.88	5	56.55	6	58.84
7	53.63	8	55.55	9	57.55	10	64.39	11	65.71	12	65.90
13	64.44	14	66.16	15	66.49	16	61.06	17	62.18	18	62.52
19	64.12	20	63.05	21	61.13	22	65.46	23	64.24	24	61.74
25	62.28	26	61.51	27	59.63	28	55.48	29	53.59	30	52.79
31	54.99	32	52.71	33	51.62	34	53.55	35	52.01	36	51.35
37	51.82	38	51.59	39	51.60	40	50.76	41	50.59	42	50.82
43	51.37	44	51.37	45	51.53	46	51.62	47	51.80	48	52.02
49	52.04	50	52.41	51	52.65	52	52.10	53	52.33	54	52.55
55	52.52	56	52.34	57	51.47	58	52.86	59	52.60	60	51.47
61	53.11	62	52.98	63	52.18	64	48.10	65	47.91	66	49.27
67	47.95	68	47.46	69	48.96	70	48.85	71	48.42	72	49.51
73	49.42	74	52.32	75	58.48	76	51.94	77	56.38	78	59.60
79	53.83	80	57.12	81	59.59	82	64.99	83	64.86	84	63.83
85	65.70	86	65.11	87	66.18	88	62.35	89	59.82	90	57.10
91	64.39	92	62.35	93	59.92	94	63.36	95	61.71	96	59.46
97	52.58	98	51.86	99	52.36	100	51.26	101	53.86	102	52.37
103	48.07	104	44.92	105	44.12	106	48.10	107	46.00	108	45.74
109	50.27	110	49.21	111	48.95	112	45.59	113	45.67	114	47.48
115	47.75	116	49.05	117	49.52	118	44.90	119	44.92	120	45.32
121	46.75	122	46.39	123	46.29	124	49.21	125	48.94	126	48.41
127	45.90	128	46.22	129	44.97	130	45.43	131	46.38	132	47.89
133	49.96	134	51.51	135	53.56	136	47.60	137	49.41	138	53.08
139	46.96	140	48.34	141	53.13	142	57.85	143	58.21	144	58.69
145	58.77	146	62.04	147	62.32	148	57.53	149	56.13	150	54.21
151	57.53	152	54.98	153	52.82	154	56.64	155	53.07	156	51.50
157	50.39	158	49.35	159	49.92	160	49.00	161	50.82	162	50.60
163	50.26	164	50.41	165	50.65	166	48.66	167	48.35	168	49.35
169	48.97	170	47.28	171	49.22	172	50.37	173	50.63	174	50.98
175	51.27	176	54.24	177	54.37	178	51.72	179	51.14	180	50.49
181	50.83	182	49.86	183	48.86	184	50.46	185	48.74	186	48.11
187	47.21	188	47.06	189	47.15	190	46.91	191	48.63	192	48.54
193	44.30	194	46.16	195	50.51	196	44.97	197	47.58	198	52.66
199	46.52	200	49.44	201	54.75	202	47.11	203	46.56	204	47.86
205	46.43	206	45.95	207	48.40	208	45.99	209	46.81	210	50.18
211	58.00	212	58.41	213	58.30	214	56.97	215	54.40	216	53.37
217	52.53	218	52.18	219	54.88	220	56.02	221	56.09	222	54.86
223	53.86	224	53.78	225	53.69	226	54.02	227	53.85	228	53.26
229	51.16	230	50.79	231	48.47	232	47.90				
301	-272.80										





# APPENDIX B. PANSAT STEADY STATE TEMPS IN SHADOW

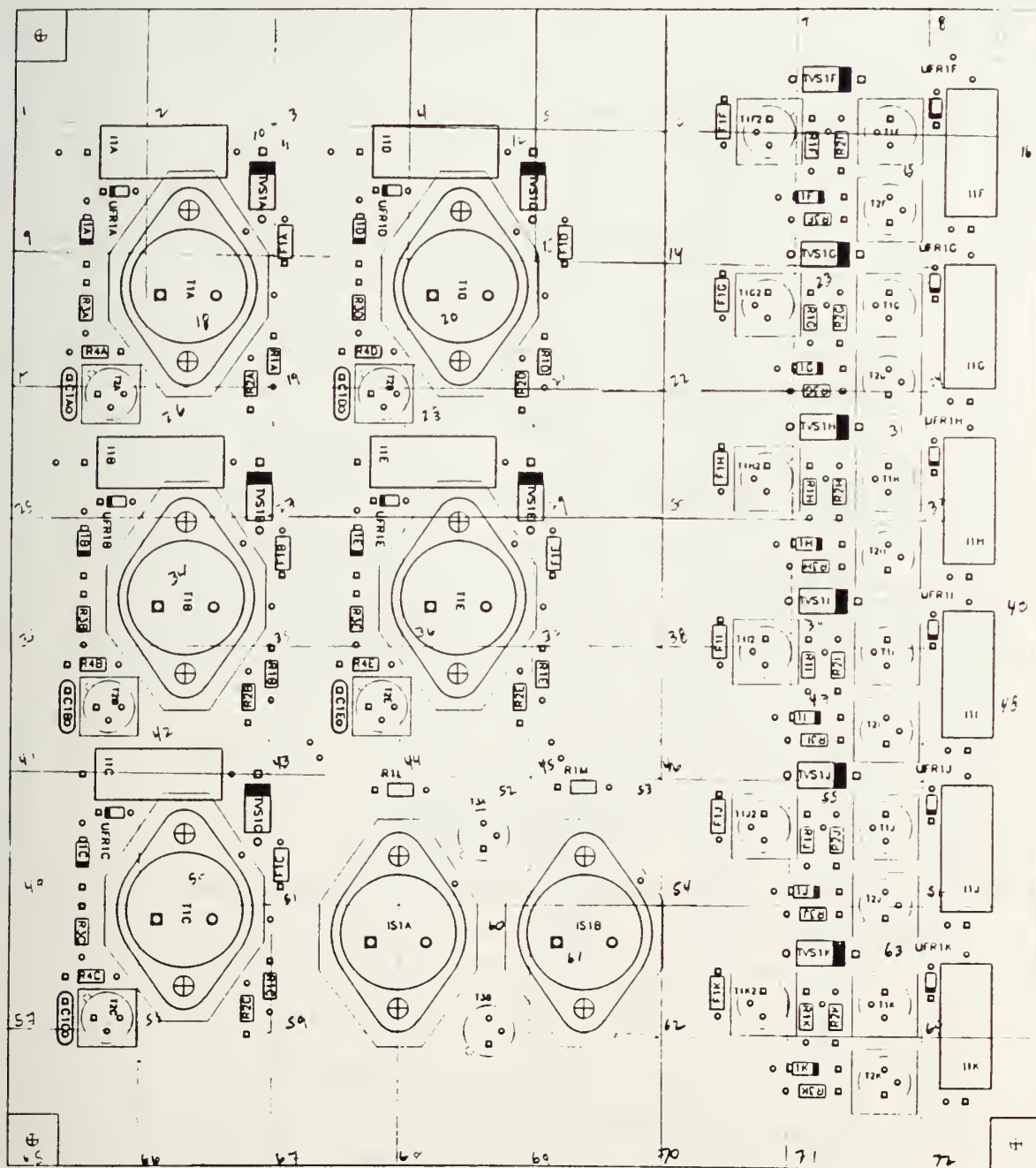
Page No. 1

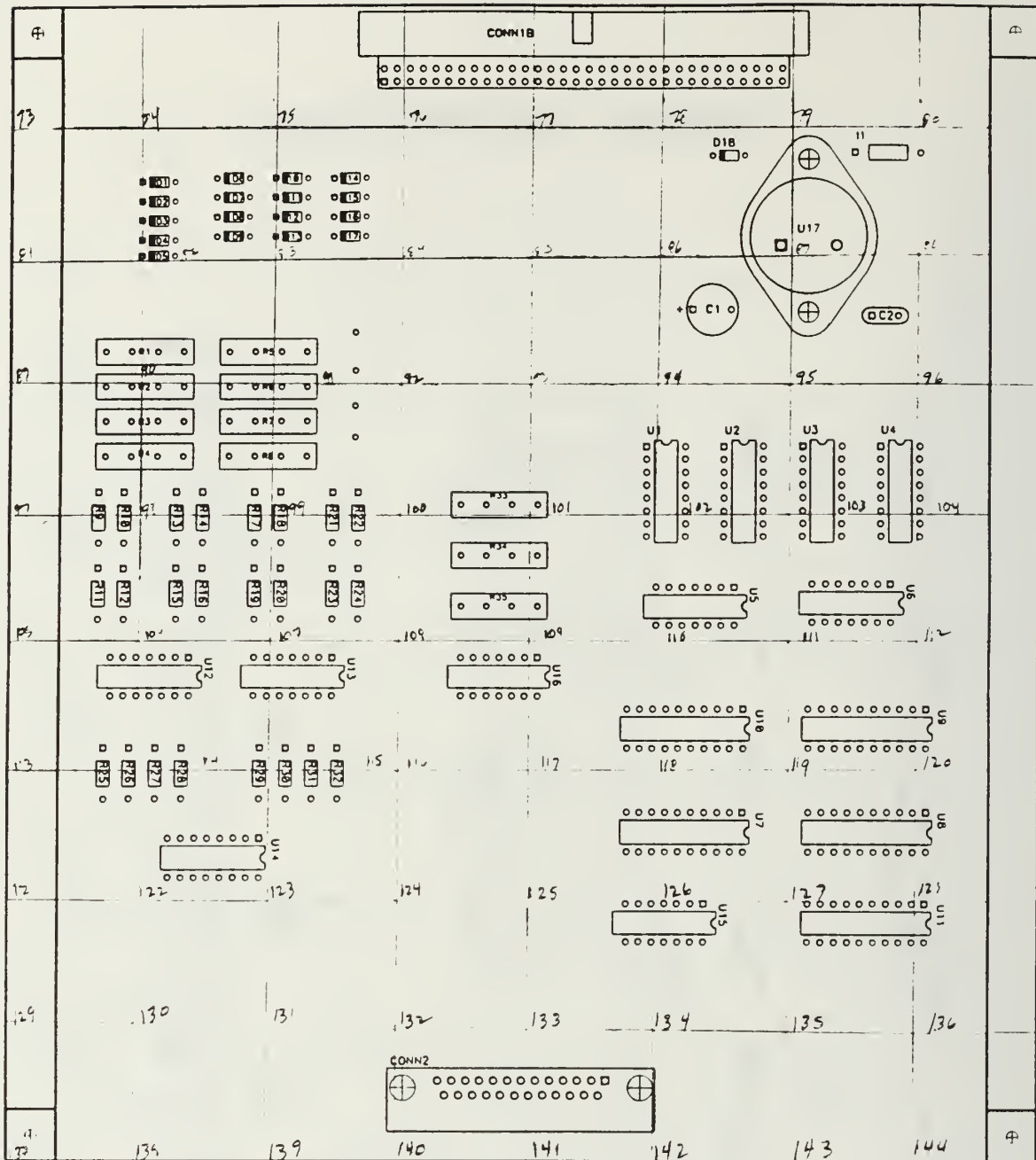
PANSAT - STEADY STATE - SHADOW ZONE - WITH INTERNAL HEAT DISSIPATION  
Temperatures, degC

1	-19.14	2	-19.99	3	-20.56	4	-18.34	5	-19.32	6	-19.99
7	-16.10	8	-17.14	9	-17.65	10	-21.82	11	-21.92	12	-21.63
13	-20.83	14	-20.72	15	-19.87	16	-18.65	17	-18.29	18	-15.44
19	-20.86	20	-20.75	21	-20.73	22	-20.03	23	-20.14	24	-20.19
25	-17.47	26	-17.81	27	-17.93	28	-20.84	29	-20.63	30	-19.70
31	-20.23	32	-19.81	33	-18.54	34	-18.17	35	-17.85	36	-16.89
37	-15.75	38	-14.72	39	-13.46	40	-14.94	41	-13.27	42	-11.58
43	-13.84	44	-12.45	45	-11.21	46	-10.08	47	-9.24	48	-8.99
49	-7.89	50	-6.78	51	-6.50	52	-8.06	53	-7.29	54	-7.12
55	-9.28	56	-9.74	57	-10.81	58	-6.96	59	-7.61	60	-9.01
61	-7.67	62	-8.18	63	-9.19	64	-14.46	65	-15.52	66	-16.85
67	-13.05	68	-14.63	69	-15.68	70	-12.57	71	-13.70	72	-14.61
73	-22.36	74	-24.09	75	-25.30	76	-22.12	77	-23.14	78	-24.54
79	-20.75	80	-21.69	81	-22.36	82	-25.89	83	-25.88	84	-24.88
85	-24.87	86	-23.35	87	-23.37	88	-25.80	89	-25.26	90	-24.27
91	-24.93	92	-24.34	93	-22.48	94	-22.66	95	-22.31	96	-21.87
97	-23.37	98	-23.22	99	-22.69	100	-22.34	101	-22.11	102	-21.47
103	-22.51	104	-20.87	105	-18.13	106	-21.13	107	-19.28	108	-16.09
109	-19.15	110	-17.80	111	-15.57	112	-15.17	113	-15.02	114	-12.88
115	-12.24	116	-11.56	117	-10.70	118	-15.61	119	-17.25	120	-18.41
121	-13.71	122	-14.89	123	-15.65	124	-12.85	125	-13.81	126	-14.76
127	-19.81	128	-20.18	129	-18.39	130	-18.92	131	-16.96	132	-18.62
133	-15.03	134	-15.38	135	-17.24	136	-15.21	137	-17.17	138	-18.68
139	-14.50	140	-17.04	141	-18.87	142	-18.88	143	-16.47	144	-19.43
145	-19.44	146	-19.59	147	-19.64	148	-17.73	149	-17.47	150	-17.44
151	-19.37	152	-19.00	153	-18.53	154	-19.44	155	-18.79	156	-18.08
157	-18.05	158	-17.21	159	-18.05	160	-17.13	161	-17.16	162	-16.83
163	-13.53	164	-11.66	165	-10.02	166	-13.95	167	-11.47	168	-8.60
169	-14.16	170	-11.15	171	-7.36	172	-8.40	173	-7.93	174	-7.32
175	-6.85	176	-2.19	177	-2.04	178	-8.09	179	-9.45	180	-9.83
181	-6.35	182	-7.57	183	-9.09	184	-5.65	185	-7.91	186	-9.34
187	-12.97	188	-14.11	189	-12.09	190	-13.32	191	-11.10	192	-11.38
193	-20.05	194	-22.76	195	-24.46	196	-21.20	197	-24.10	198	-25.41
199	-21.99	200	-24.54	201	-25.83	202	-10.78	203	-13.59	204	-15.85
205	-12.25	206	-14.59	207	-16.46	208	-13.09	209	-15.07	210	-17.72
211	-18.92	212	-19.12	213	-19.11	214	-18.23	215	-15.99	216	-14.82
217	-14.09	218	-14.19	219	-13.66	220	-14.04	221	-14.20	222	-13.39
223	-12.32	224	-11.53	225	-11.48	226	-12.52	227	-13.80	228	-12.66
229	-14.06	230	-13.39	231	-14.59	232	-13.79				
301	-272.80										



# APPENDIX C. EPS NODE DIVISIONS





# APPENDIX D. THANSS/TASS INPUT FILE

PRINTED CIRCUIT BOARDS - S. PATTERSON - RUN B

144	3	0	0	0	0	0	0	0	1
0	0	0							
300	50	6	2	4	6	0	0	0	0
.500000E-01	.666670				12	.800000		77.0000	
92.3000	92.3000		92.3000						
5	21	91		733		3011		3033	
.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03					
5	11	31		101		743		3033	
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03					
5	21	41		111		753		3033	
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03					
5	31	51		121		763		3033	
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03					
5	41	61		131		773		3033	
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03					
.6	51	71		141		783		3033	9991
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.102390E-01				
6	61	81		151		793		3033	9991
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E-02				
6	71	161		803		3011		3033	9991
.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.102390E-01				
7	11	101		171		813		3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.682600E-03			9
7	21	91		111		181		823	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.139933			
7	31	101		121		191		833	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.139933			9
7	41	111		131		201		843	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.546080E			
7	51	121		141		211		853	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E			9
7	61	131		151		221		863	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E			9
7	71	141		161		231		873	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.170650E			9
7	81	151		241		883		3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.000000	.801852E-03	.204780E			9
7	91	181		251		893		3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.170650E			9
7	101	171		191		261		903	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.204780E			9
7	111	181		201		271		913	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.136520E			9
7	121	191		211		281		923	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.136520E			9
7	131	201		221		291		933	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E			9
7	141	211		231		301		943	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.136520E			9
7	151	221		241		311		953	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.136520E			9
7	161	231		321		963		3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.307170E			9
7	171	261		331		973		3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.682600E			9
7	181	251		271		341		983	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.139933			9
7	191	261		281		351		993	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E			



144	3	0	0	0	0	0	0	1
0	0	0						
300	50	6	2	4	6	0	0	0
.500000E-01	.666670				12	.800000	77.0000	
92.3000	92.3000	92.3000						
5	21	91	733	3011	3033			
.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03				
5	11	31	101	743	3033			
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03				
5	21	41	111	753	3033			
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03				
5	31	51	121	763	3033			
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03				
5	41	61	131	773	3033			
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03				
6	51	71	141	783	3033		9991	
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.102390E-01			
6	61	81	151	793	3033		9991	
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E-02			
6	71	161	803	3011	3033		9991	
.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.102390E-01			
7	11	101	171	813	3011	3033		9
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.682600E-03		9
7	21	91	111	181	823	3033		
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.139933		
7	31	101	121	191	833	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.139933		
7	41	111	131	201	843	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.546080E-03		
7	51	121	141	211	853	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E-03		
7	61	131	151	221	863	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E-03		
7	71	141	161	231	873	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.170650E-03		
7	81	151	241	883	3011	3033		9
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.000000	.801852E-03	.204780E-03		
7	91	181	251	893	3011	3033		9
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.170650E-03		
7	101	171	191	261	903	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.204780E-03		
7	111	181	201	271	913	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.136520E-03		
7	121	191	211	281	923	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.136520E-03		
7	131	201	221	291	933	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E-03		
7	141	211	231	301	943	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.136520E-03		
7	151	221	241	311	953	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.136520E-03		
7	161	231	321	963	3011	3033		9
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.307170E-03		
7	171	261	331	973	3011	3033		9
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.682600E-03		
7	181	251	271	341	983	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.139933		
7	191	261	281	351	993	3033		9
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E-03		

201	271	291	361	1003	3033	
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.102390
6	211	281	301	371	1013	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
7	221	291	311	381	1023	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.341300E
7	231	301	321	391	1033	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.102390E
6	241	311	401	1043	3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	
7	251	341	411	1053	3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.341300E
7	261	331	351	421	1063	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.204780E
7	271	341	361	431	1073	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.477820E
7	281	351	371	441	1083	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.273040E
7	291	361	381	451	1093	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.170650
6	301	371	391	461	1103	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
7	311	381	401	471	1113	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.102390E
7	321	391	481	1123	3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.341300E
7	331	421	491	1133	3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.784990E
7	341	411	431	501	1143	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.156998
6	351	421	441	511	1153	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
6	361	431	451	521	1163	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
7	371	441	461	531	1173	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.682600E
7	381	451	471	541	1183	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.341300E
7	391	461	481	551	1193	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.170650E
7	401	471	561	1203	3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.000000	.801852E-03	.341300E
7	411	501	571	1213	3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.784990E
7	421	491	511	581	1223	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.341300E
7	431	501	521	591	1233	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.853250E
6	441	511	531	601	1243	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
6	451	521	541	611	1253	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
6	461	531	551	621	1263	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
6	471	541	561	631	1273	3033
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
6	481	551	641	1283	3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	
7	491	581	651	1293	3011	3033
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	.102390E

.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	.784990E
6 511	581	601	671	1313	3033	
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
6 521	591	611	681	1323	3033	
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
6 531	601	621	691	1333	3033	
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
6 541	611	631	701	1343	3033	
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
6 551	621	641	711	1353	3033	
.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03	
6 561	631	721	1363	3011	3033	
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03	
5 571	661	1373	3011	3033		
.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03		
5 581	651	671	1383	3033		
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03		
5 591	661	681	1393	3033		
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03		
5 601	671	691	1403	3033		
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03		
5 611	681	701	1413	3033		
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03		
5 621	691	711	1423	3033		
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03		
5 631	701	721	1433	3033		
.759341E-01	.759341E-01	.759341E-01	.801852E-03	.801852E-03		
5 641	711	1443	3011	3033		
.759341E-01	.759341E-01	.801852E-03	.208850E-01	.801852E-03		
5 13	741	811	3011	3023		
.801852E-03	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
5 23	731	751	821	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
5 33	741	761	831	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
5 43	751	771	841	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
5 53	761	781	851	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
5 63	771	791	861	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
5 73	781	801	871	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
5 83	791	881	3011	3023		
.801852E-03	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
6 93	731	821	891	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03	
7 103	741	811	831	901	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.204780
7 113	751	821	841	911	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.180889
6 123	761	831	851	921	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	
6 133	771	841	861	931	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	
7 143	781	851	871	941	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.307170
7 153	791	861	881	951	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.426625



6	163	801	871	961	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
7	173	811	901	971	3011	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03	.102390E	
7	183	821	891	911	981	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.238910E	
7	193	831	901	921	991	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.170650E	
6	203	841	911	931	1001	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
6	213	851	921	941	1011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
7	223	861	931	951	1021	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.238910	
7	233	871	941	961	1031	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.307170	
6	243	881	951	1041	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
7	253	891	981	1051	3011	3022	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03	.238910E	
7	263	901	971	991	1061	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.511950E	
7	273	911	981	1001	1071	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341F-01	.759341E-01	.801852E-03	.238910E	
7	283	921	991	1011	1081	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.341300	
7	293	931	1001	1021	1091	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.614340E	
7	303	941	1011	1031	1101	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.614340E	
7	313	951	1021	1041	1111	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.122868	
6	323	961	1031	1121	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
6	333	971	1061	1131	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
6	343	981	1051	1071	1141	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
6	353	991	1061	1081	1151	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
7	363	1001	1071	1091	1161	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.409560	
7	373	1011	1081	1101	1171	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.102390	
7	383	1021	1091	1111	1181	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.614340E	
7	393	1031	1101	1121	1191	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.614340E	
6	403	1041	1111	1201	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
7	413	1051	1141	1211	3011	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03	.648470E	
7	423	1061	1131	1151	1221	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.648470E	
7	433	1071	1141	1161	1231	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.648470E	
6	443	1081	1151	1171	1241	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
7	453	1091	1161	1181	1251	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.341300E	

7	463	1101	1171	1191	1261	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.511950E
7	473	1111	1181	1201	1271	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.853250E
6	483	1121	1191	1281	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
6	493	1131	1221	1291	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
7	503	1141	1211	1231	1301	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.853250E	
6	513	1151	1221	1241	1311	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
6	523	1161	1231	1251	1321	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
7	533	1171	1241	1261	1331	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.341300E	
7	543	1181	1251	1271	1341	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.511950E	
7	553	1191	1261	1281	1351	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.853250E	
6	563	1201	1271	1361	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
6	573	1211	1301	1371	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
6	583	1221	1291	1311	1381	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
6	593	1231	1301	1321	1391	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
6	603	1241	1311	1331	1401	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03		
7	613	1251	1321	1341	1411	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.341300E	
7	623	1261	1331	1351	1421	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.511950E	
7	633	1271	1341	1361	1431	3023	9
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.759341E-01	.801852E-03	.853250E	
6	643	1281	1351	1441	3011	3023	
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.208850E-01	.801852E-03		
5	653	1291	1381	3011	3023		
.801852E-03	.759341E-01	.759341E-01	.208850E-01	.801852E-03			
5	663	1301	1371	1391	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03			
5	673	1311	1381	1401	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03			
5	683	1321	1391	1411	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03			
5	693	1331	1401	1421	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03			
5	703	1341	1411	1431	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03			
5	713	1351	1421	1441	3023		
.801852E-03	.759341E-01	.759341E-01	.759341E-01	.801852E-03			
5	723	1361	1431	3011	3023		
.801852E-03	.759341E-01	.759341E-01	.208850E-01	.801852E-03			



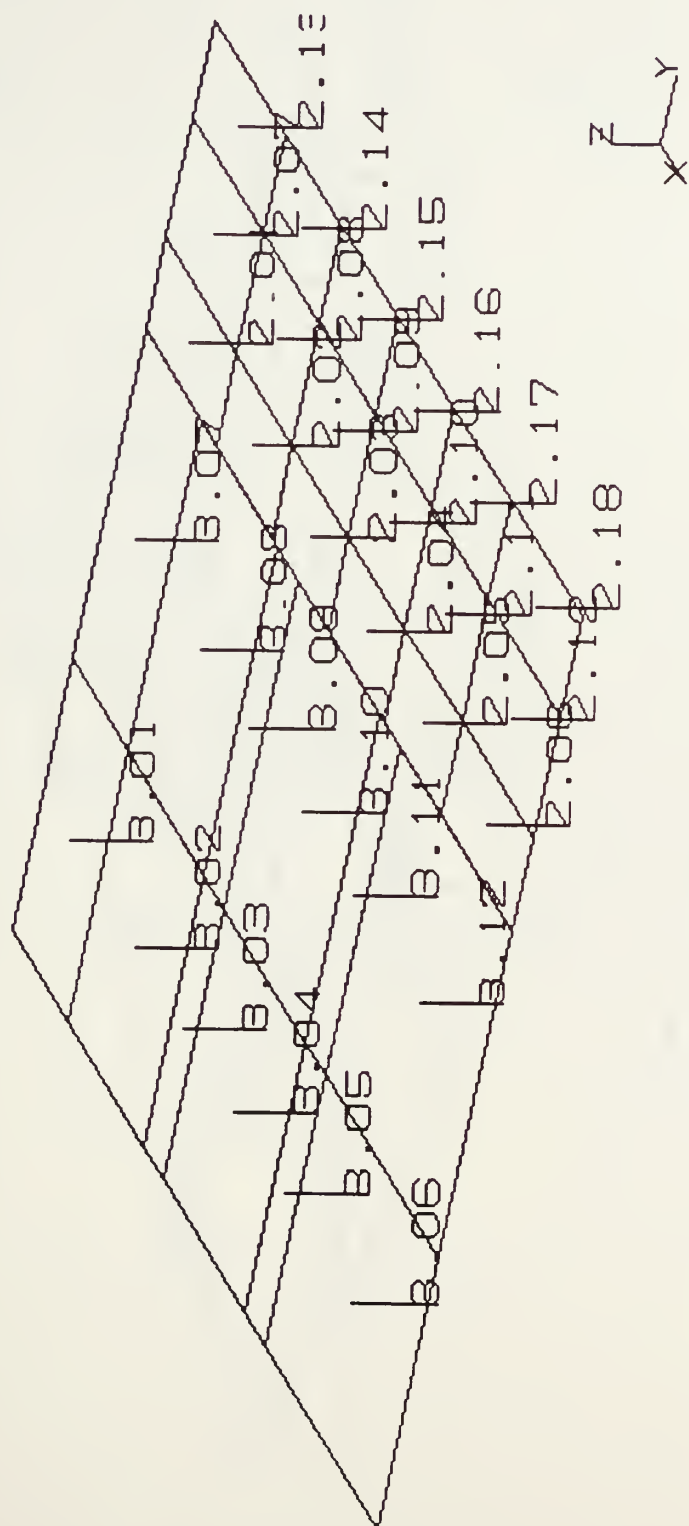
# APPENDIX E. HEAT DISSIPATIONS BY NODE

NODE	WATTS	NODE	WATTS	NODE	WATTS	NODE	WATT S
8	.003	25	.02	49	.023	102	.018
7	.002	26	.041	90	.010	103	.036
8	.003	27	.020	91	.025	108	.120
8	.020	28	.030	57	.003	109	.030
16	.041	90	.001	98	.023	110	.018
11	.011	31	.003	82	.000	111	.018
12	.016	33	.001	83	.053	113	.015
13	.002	34	.006	86	.090	114	.019
14	.002	39	.014	87	.125	118	.015
19	.005	36	.008	89	.003	117	.010
16	.005	37	.050	90	.007	118	.010
17	.005	39	.003	91	.008	118	.025
16	.006	40	.001	94	.070	122	.025
19	.004	41	.023	95	.000	125	.010
20	.004	47	.046	97	.007	125	.015
21	.002	45	.002	86	.015	127	.025
22	.004	46	.001	99	.007	133	.010
23	.004	47	.005	100	.100	134	.010
24	.009	48	.001	101	.018	135	.025

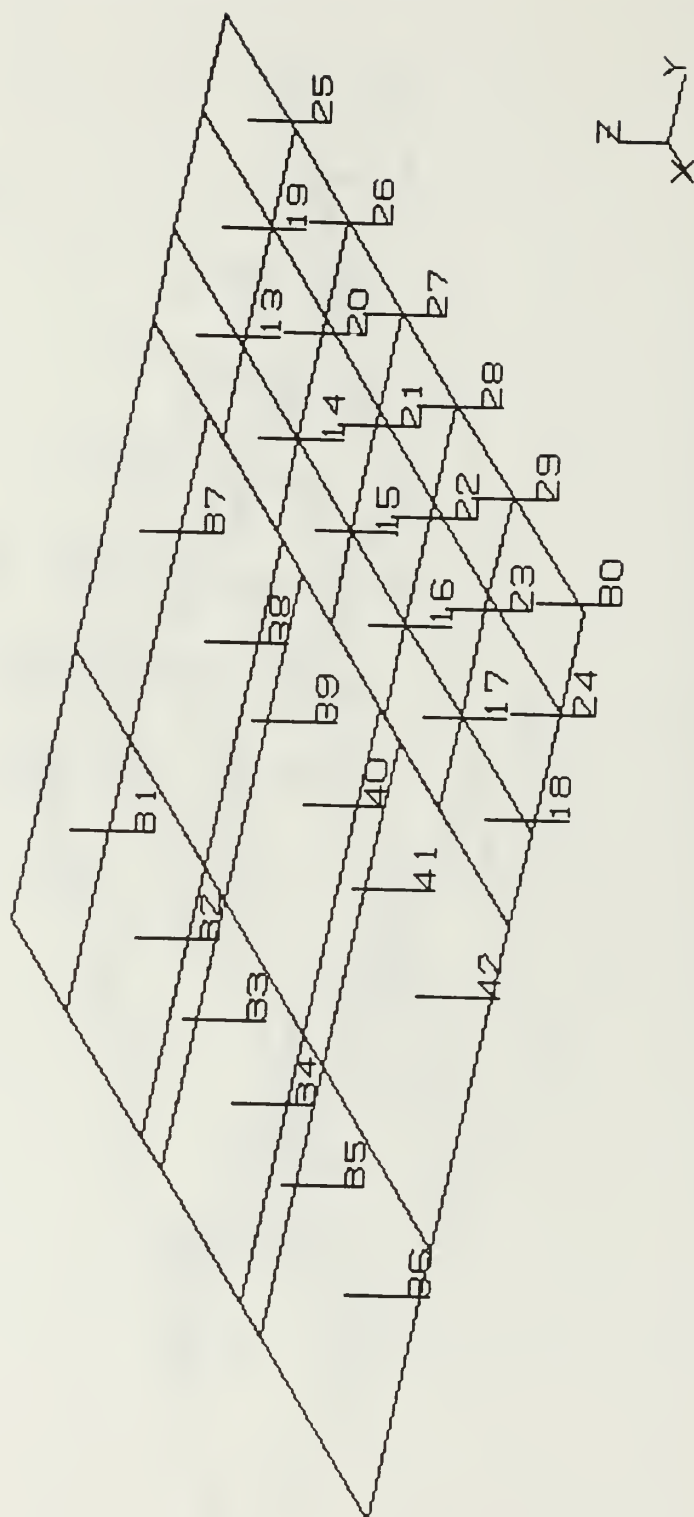
PCB HEAT DISSIPATIONS BY NODE



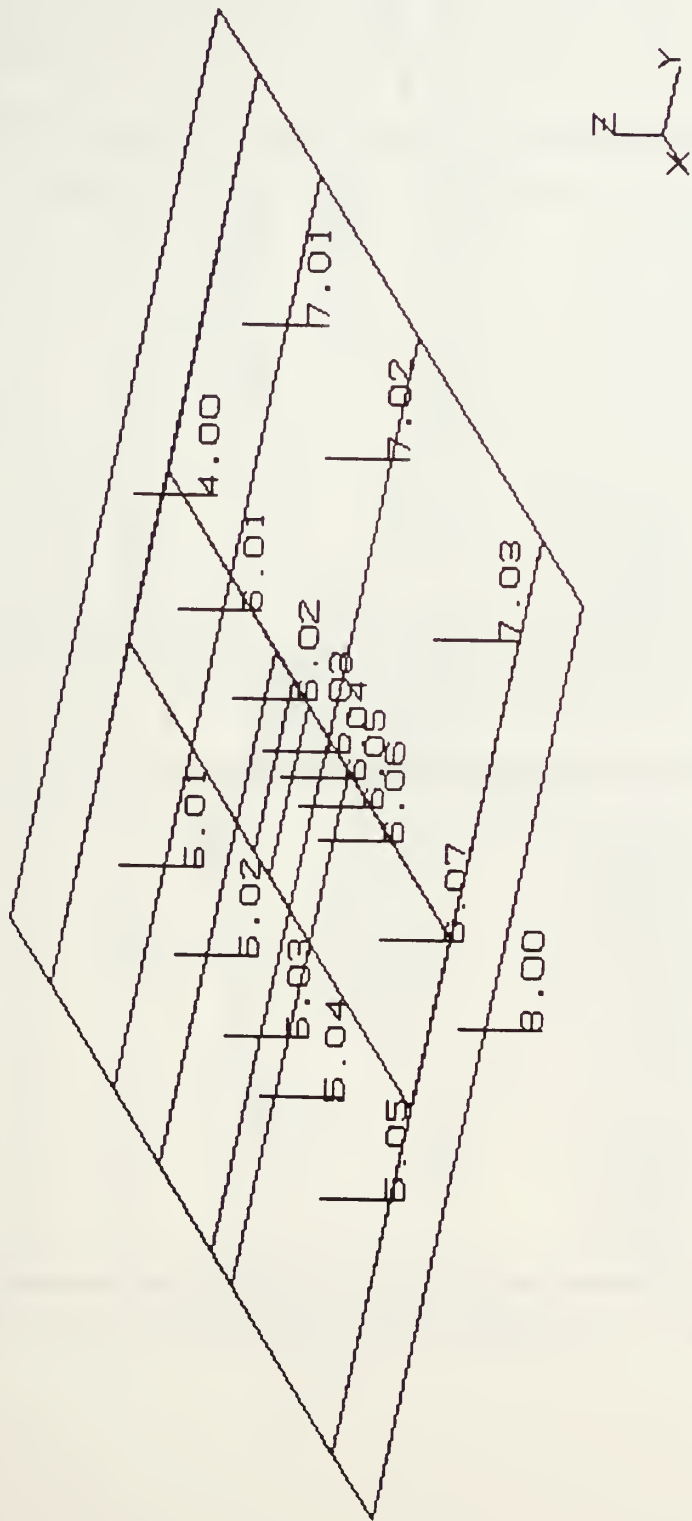
# APPENDIX F. SURFACE/NODE NUMBERS FOR TOP PCB



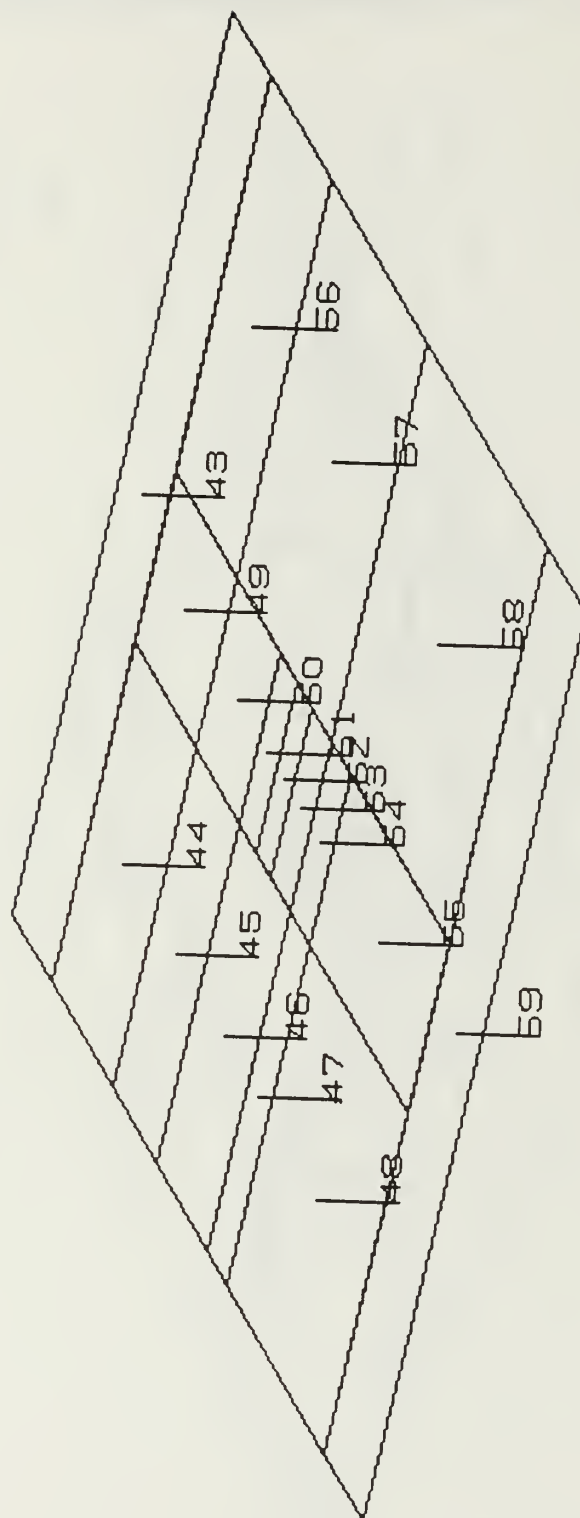
SURFACE NUMBERS FOR TOP PCB



APPENDIX G. SURFACE/NODE NUMBERS FOR BOTTOM PCB



SURFACE NUMBERS FOR BOTTOM PCB





## APPENDIX H. OPTICAL PROPERTY DATA FOR EPS

[illegible][illegible]

[illegible]

# APPENDIX I. THERMAL MASS FOR THE EPS

NODE	X/Y	Y/Z	thickness	kg/cubic m ro(Cu/Al/poly)	cal/kg c specific heat	CONV FACTOR	INTO M	cubic meters VOLUME	THERMAL MASS
901	9 4	1 569	0.2	2787	0.199	69 78	61024	4 8337E-05	1 870687
902	2 1	1 569	0.2	2787	0.199	69 78	61024	1 07987E-05	0 417919
903	2 1	1 569	0.2	2787	0.199	69 78	61024	1 07987E-05	0 417919
904	2 1	1 569	0.2	2787	0.199	69 78	61024	1 07987E-05	0 417919
905	2 1	1 569	0.2	2787	0.199	69 78	61024	1 07987E-05	0 417919
906	9 4	8 4	0.2	2787	0.199	69 78	61024	0 000258783	10 01515
907	9 4	1 569	0.2	2787	0.199	69 78	61024	4 8337E-05	1 870687
908	2 1	1 569	0.2	2787	0.199	69 78	61024	1 07987E-05	0 417919
909	2 1	1 569	0.2	2787	0.199	69 78	61024	1 07987E-05	0 417919
910	2 1	1 569	0.2	2787	0.199	69 78	61024	1 07987E-05	0 417919
911	2 1	1 569	0.2	2787	0.199	69 78	61024	1 07987E-05	0 417919
912	9 4	8 4	0.2	2787	0.199	69 78	61024	0 000258783	10 01515
913	9 4	8 4	0.125	2787	0.199	69 78	61024	0 00016174	6 259469
921	8 4	0.25	0.2	2787	0.199	69 78	61024	6 88254E-06	0 26636
922	8 4	0.375	0.2	2787	0.199	69 78	61024	1 03238E-05	0 399541
923	8 4	0.199	0.2	2787	0.199	69 78	61024	5 4785E-06	0 212023
924	8 4	2.5	0.2	2787	0.199	69 78	61024	6 88254E-05	2 663604
925	8 4	0.375	0.2	2787	0.199	69 78	61024	1 03238E-05	0 399541
926	8 4	0.199	0.2	2787	0.199	69 78	61024	5 4785E-06	0 212023
601	1 375	2 375	0.00134	8666	0.098	69 78	61024	7 17085E-08	0 00425
602	1 875	2 375	0.00134	8666	0.098	69 78	61024	9 77843E-08	0 005795
603	0.5	2 375	0.00134	8666	0.098	69 78	61024	2 60758E-08	0 001545
604	2	2 375	0.00134	8666	0.098	69 78	61024	1 04303E-07	0 006181
605	0.5	2 375	0.00134	8666	0.098	69 78	61024	2 60758E-08	0 001545
606	2.75	2 375	0.00134	8666	0.098	69 78	61024	1 43417E-07	0 008499
607	1 375	2 875	0.00134	8666	0.098	69 78	61024	8 6805E-08	0 005144
608	1 875	2 875	0.00134	8666	0.098	69 78	61024	1 1837E-07	0 007015
609	0.5	2 875	0.00134	8666	0.098	69 78	61024	3 15654E-08	0 001871
610	2	2 875	0.00134	8666	0.098	69 78	61024	1 26262E-07	0 007483
611	0.5	2 875	0.00134	8666	0.098	69 78	61024	3 15654E-08	0 001871
612	2.75	2 875	0.00134	8666	0.098	69 78	61024	1 7361E-07	0 010288
613	1.75	0.8125	0.00134	8666	0.098	69 78	61024	3 12223E-08	0 00185



614	1.375	0.8125	0.00134	8666	0.098	69.78	61024	2.45318E-08	0.001454
615	1.375	0.8125	0.00134	8666	0.098	69.78	61024	2.45318E-08	0.001454
616	1.375	0.8125	0.00134	8666	0.098	69.78	61024	2.45318E-08	0.001454
617	1.375	0.8125	0.00134	8666	0.098	69.78	61024	2.45318E-08	0.001454
618	1.75	0.8125	0.00134	8666	0.098	69.78	61024	3.12223E-08	0.00185
619	1.75	1.0625	0.00134	8666	0.098	69.78	61024	4.08292E-08	0.00242
620	1.375	1.0625	0.00134	8666	0.098	69.78	61024	3.20801E-08	0.001901
621	1.375	1.0625	0.00134	8666	0.098	69.78	61024	3.20801E-08	0.001901
622	1.375	1.0625	0.00134	8666	0.098	69.78	61024	3.20801E-08	0.001901
623	1.375	1.0625	0.00134	8666	0.098	69.78	61024	3.20801E-08	0.001901
624	1.75	1.0625	0.00134	8666	0.098	69.78	61024	4.08292E-08	0.00242
625	1.375	0.875	0.00134	8666	0.098	69.78	61024	2.64189E-08	0.001566
626	1.375	0.875	0.00134	8666	0.098	69.78	61024	2.64189E-08	0.001566
627	1.375	0.875	0.00134	8666	0.098	69.78	61024	2.64189E-08	0.001566
628	1.375	0.875	0.00134	8666	0.098	69.78	61024	2.64189E-08	0.001566
629	1.375	0.875	0.00134	8666	0.098	69.78	61024	2.64189E-08	0.001566
630	1.75	0.875	0.00134	8666	0.098	69.78	61024	3.36241E-08	0.001993
1601	8	1	0.00134	8666	0.098	69.78	61024	1.75669E-07	0.01041
1602	3	1.563	0.00134	8666	0.098	69.78	61024	1.02964E-07	0.006102
1603	3	1.125	0.00134	8666	0.098	69.78	61024	7.41102E-08	0.004392
1604	3	1.3125	0.00134	8666	0.098	69.78	61024	8.64619E-08	0.005124
1605	3	0.5	0.00134	8666	0.098	69.78	61024	3.29379E-08	0.001952
1606	3	2.5	0.00134	8666	0.098	69.78	61024	1.64689E-07	0.00976
1607	1.5	1.563	0.00134	8666	0.098	69.78	61024	5.14819E-08	0.003051
1608	1.5	1.125	0.00134	8666	0.098	69.78	61024	3.70551E-08	0.002196
1609	1.5	1.4375	0.00134	8666	0.098	69.78	61024	4.73482E-08	0.002806
1610	1.5	0.375	0.00134	8666	0.098	69.78	61024	1.23517E-08	0.000732
1611	1.5	0.5	0.00134	8666	0.098	69.78	61024	1.64689E-08	0.000976
1612	1.5	0.5	0.00134	8666	0.098	69.78	61024	1.64689E-08	0.000976
1613	1.5	2.5	0.00134	8666	0.098	69.78	61024	8.23447E-08	0.00488
1614	3.5	1.563	0.00134	8666	0.098	69.78	61024	1.20124E-07	0.007119
1615	3.5	2.4375	0.00134	8666	0.098	69.78	61024	1.87334E-07	0.011102
1616	3.5	3	0.00134	8666	0.098	69.78	61024	2.30565E-07	0.013664
1617	3.5	1	0.00134	8666	0.098	69.78	61024	7.6855E-08	0.004555
501	1.375	2.375	0.01933	1950	0.31	69.78	61024	1.03442E-06	0.043634
502	1.875	2.375	0.01933	1950	0.31	69.78	61024	1.41057E-06	0.059501
503	0.5	2.375	0.01933	1950	0.31	69.78	61024	3.76153E-07	0.015867

504	2	2.375	0.01933	1950	0.31	69.78	61024	1.50461E-06	0.063468
505	0.5	2.375	0.01933	1950	0.31	69.78	61024	3.76153E-07	0.015867
506	2.75	2.375	0.01933	1950	0.31	69.78	61024	2.06884E-06	0.087268
507	1.375	2.875	0.01933	1950	0.31	69.78	61024	1.25219E-06	0.05282
508	1.875	2.875	0.01933	1950	0.31	69.78	61024	1.70754E-06	0.072027
509	0.5	2.875	0.01933	1950	0.31	69.78	61024	4.55343E-07	0.019207
510	2	2.875	0.01933	1950	0.31	69.78	61024	1.82137E-06	0.076829
511	0.5	2.875	0.01933	1950	0.31	69.78	61024	4.55343E-07	0.019207
512	2.75	2.875	0.01933	1950	0.31	69.78	61024	2.50439E-06	0.10564
513	1.75	0.8125	0.01933	1950	0.31	69.78	61024	4.50394E-07	0.018999
514	1.375	0.8125	0.01933	1950	0.31	69.78	61024	3.53881E-07	0.014927
515	1.375	0.8125	0.01933	1950	0.31	69.78	61024	3.53881E-07	0.014927
516	1.375	0.8125	0.01933	1950	0.31	69.78	61024	3.53881E-07	0.014927
517	1.375	0.8125	0.01933	1950	0.31	69.78	61024	3.53881E-07	0.014927
518	1.75	0.8125	0.01933	1950	0.31	69.78	61024	4.50394E-07	0.018999
519	1.75	1.0625	0.01933	1950	0.31	69.78	61024	5.88977E-07	0.024844
520	1.375	1.0625	0.01933	1950	0.31	69.78	61024	4.62767E-07	0.01952
521	1.375	1.0625	0.01933	1950	0.31	69.78	61024	4.62767E-07	0.01952
522	1.375	1.0625	0.01933	1950	0.31	69.78	61024	4.62767E-07	0.01952
523	1.375	1.0625	0.01933	1950	0.31	69.78	61024	4.62767E-07	0.01952
524	1.75	1.0625	0.01933	1950	0.31	69.78	61024	5.88977E-07	0.024844
525	1.375	0.875	0.01933	1950	0.31	69.78	61024	3.81103E-07	0.016076
526	1.375	0.875	0.01933	1950	0.31	69.78	61024	3.81103E-07	0.016076
527	1.375	0.875	0.01933	1950	0.31	69.78	61024	3.81103E-07	0.016076
528	1.375	0.875	0.01933	1950	0.31	69.78	61024	3.81103E-07	0.016076
529	1.375	0.875	0.01933	1950	0.31	69.78	61024	3.81103E-07	0.016076
530	1.75	0.875	0.01933	1950	0.31	69.78	61024	4.8504E-07	0.02046
1501	8	1	0.01933	1950	0.31	69.78	61024	2.53408E-06	0.106893
1502	3	1.563	0.01933	1950	0.31	69.78	61024	1.48529E-06	0.062653
1503	3	1.125	0.01933	1950	0.31	69.78	61024	1.06907E-06	0.045095
1504	3	1.3125	0.01933	1950	0.31	69.78	61024	1.24724E-06	0.052611
1505	3	0.5	0.01933	1950	0.31	69.78	61024	4.75141E-07	0.020042
1506	3	2.5	0.01933	1950	0.31	69.78	61024	2.3757E-06	0.100212
1507	1.5	1.563	0.01933	1950	0.31	69.78	61024	7.42645E-07	0.031326
1508	1.5	1.125	0.01933	1950	0.31	69.78	61024	5.34534E-07	0.022548
1509	1.5	1.4375	0.01933	1950	0.31	69.78	61024	6.83015E-07	0.028811
1510	1.5	0.375	0.01933	1950	0.31	69.78	61024	1.78178E-07	0.007516



PIN THERMAL MASSES												
NODE	# OF PINS	pi	RADIUS	HEIGHT	VOLUME	cal/kg C c	kg/cubic m ro	CONV FACTOR	cubic in to cubic m	THERMAL MASS		
2011	6	3.14159	0.0165	0.01933	9.92E-05	0.11	8378	69.78	61024	0.000105		
2012	6	3.14159	0.0165	0.00134	6.88E-06	0.11	8378	69.78	61024	7.25E-06		
2021	23	3.14159	0.0165	0.01933	0.00038	0.11	8378	69.78	61024	0.000401		
2022	23	3.14159	0.0165	0.00134	2.64E-05	0.11	8378	69.78	61024	2.78E-05		
2031	4	3.14159	0.0165	0.01933	6.61E-05	0.11	8378	69.78	61024	6.97E-05		
2032	4	3.14159	0.0165	0.00134	4.58E-06	0.11	8378	69.78	61024	4.83E-06		
2041	25	3.14159	0.0165	0.01933	0.000413	0.11	8378	69.78	61024	0.000436		
2042	25	3.14159	0.0165	0.00134	2.87E-05	0.11	8378	69.78	61024	3.02E-05		
2051	3	3.14159	0.0165	0.01933	4.96E-05	0.11	8378	69.78	61024	5.23E-05		
2052	3	3.14159	0.0165	0.00134	3.44E-06	0.11	8378	69.78	61024	3.62E-06		
2121	12	3.14159	0.0165	0.01933	0.000198	0.11	8378	69.78	61024	0.000209		
2122	12	3.14159	0.0165	0.00134	1.38E-05	0.11	8378	69.78	61024	1.45E-05		
2131	8	3.14159	0.0165	0.01933	0.000132	0.11	8378	69.78	61024	0.000139		
2132	8	3.14159	0.0165	0.00134	9.17E-06	0.11	8378	69.78	61024	9.66E-06		
2191	14	3.14159	0.0165	0.01933	0.000231	0.11	8378	69.78	61024	0.000244		
2192	14	3.14159	0.0165	0.00134	1.6E-05	0.11	8378	69.78	61024	1.69E-05		
3011	64	3.14159	0.0165	0.01933	0.001058	0.11	8378	69.78	61024	0.001115		
3012	64	3.14159	0.0165	0.00134	7.34E-05	0.11	8378	69.78	61024	7.73E-05		
3021	34	3.14159	0.0165	0.01933	0.000562	0.11	8378	69.78	61024	0.000592		
3022	34	3.14159	0.0165	0.00134	3.9E-05	0.11	8378	69.78	61024	4.11E-05		
3031	32	3.14159	0.0165	0.01933	0.000529	0.11	8378	69.78	61024	0.000558		
3032	32	3.14159	0.0165	0.00134	3.67E-05	0.11	8378	69.78	61024	3.86E-05		
3051	28	3.14159	0.0165	0.01933	0.000463	0.11	8378	69.78	61024	0.000488		
3052	28	3.14159	0.0165	0.00134	3.21E-05	0.11	8378	69.78	61024	3.38E-05		
3141	10	3.14159	0.0165	0.01933	0.000165	0.11	8378	69.78	61024	0.000174		
3142	10	3.14159	0.0165	0.00134	1.15E-05	0.11	8378	69.78	61024	1.21E-05		
3151	100	3.14159	0.0165	0.01933	0.001653	0.11	8378	69.78	61024	0.001742		
3152	100	3.14159	0.0165	0.00134	0.000115	0.11	8378	69.78	61024	0.000121		
3161	114	3.14159	0.0165	0.01933	0.001885	0.11	8378	69.78	61024	0.001986		
3162	114	3.14159	0.0165	0.00134	0.000131	0.11	8378	69.78	61024	0.000138		



# APPENDIX J. EPS PCB BOARD DATA

Component	Designator	Subcircuit	Duty cycle	Power Dissipation, Bus = 15V (Sunlit)	Power Dissipation, Bus = 12V (Eclipse)
Inductor	I1A	DCSA Power Switch	100	0.039	0.061
Transient Voltage Suppressor	TVS1A	"	~0		
Ultra Fast Recovery Diode	UFR1A	"	~0		
12v Zener Bi-Directional	D1A	"	~0		
PMOSFET Gate Bias Resistor	R1A	"	100	0.002	0.001
PMOSFET Gate Bias Resistor	R2A	"	100	0.000	0.000
PMOSFET Gate Protection Resistor	R3A	"	100	0.003	0.003
PMOSFET	T1A	"	100	0.006	0.009
PMOSFET	T2A	"	100	0.000	0.000
Pico Fuse	F1A	"	100	0.007	0.011
Inductor	I1B	DCSB Power Switch	100	0.039	0.061
Transient Voltage Suppressor	TVS1B	"	~0		
Ultra Fast Recovery Diode	UFR1B	"	~0		
12v Zener Bi-Directional	D1B	"	~0		
PMOSFET Gate Bias Resistor	R1B	"	100	0.002	0.001
PMOSFET Gate Bias Resistor	R2B	"	100	0.000	0.000
PMOSFET Gate Protection Resistor	R3B	"	100	0.003	0.003
PMOSFET	T1B	"	100	0.006	0.009
PMOSFET	T2B	"	100	0.000	0.000
Pico Fuse	F1B	"	100	0.007	0.011
Inductor	I1C	RF Power Switch - Rx only	70	0.010	0.015
Transient Voltage Suppressor	TVS1C	"	~0		
Ultra Fast Recovery Diode	UFR1C	"	~0		
12v Zener Bi-Directional	D1C	"	~0		
PMOSFET Gate Bias Resistor	R1C	"	100	0.002	0.001
PMOSFET Gate Bias Resistor	R2C	"	100	0.000	0.000
PMOSFET Gate Protection Resistor	R3C	"	70	0.003	0.003
PMOSFET	T1C	"	70	0.006	0.009
PMOSFET	T2C	"	70	0.000	0.000
Pico Fuse	F1C	"	70	0.002	0.003
Inductor	I1C	RF Power Switch - Rx and Tx	30	0.088	0.138
Transient Voltage Suppressor	TVS1C	"	~0		
Ultra Fast Recovery Diode	UFR1C	"	~0		
12v Zener Bi-Directional	D1C	"	~0		
PMOSFET Gate Bias Resistor	R1C	"	30	0.002	0.001

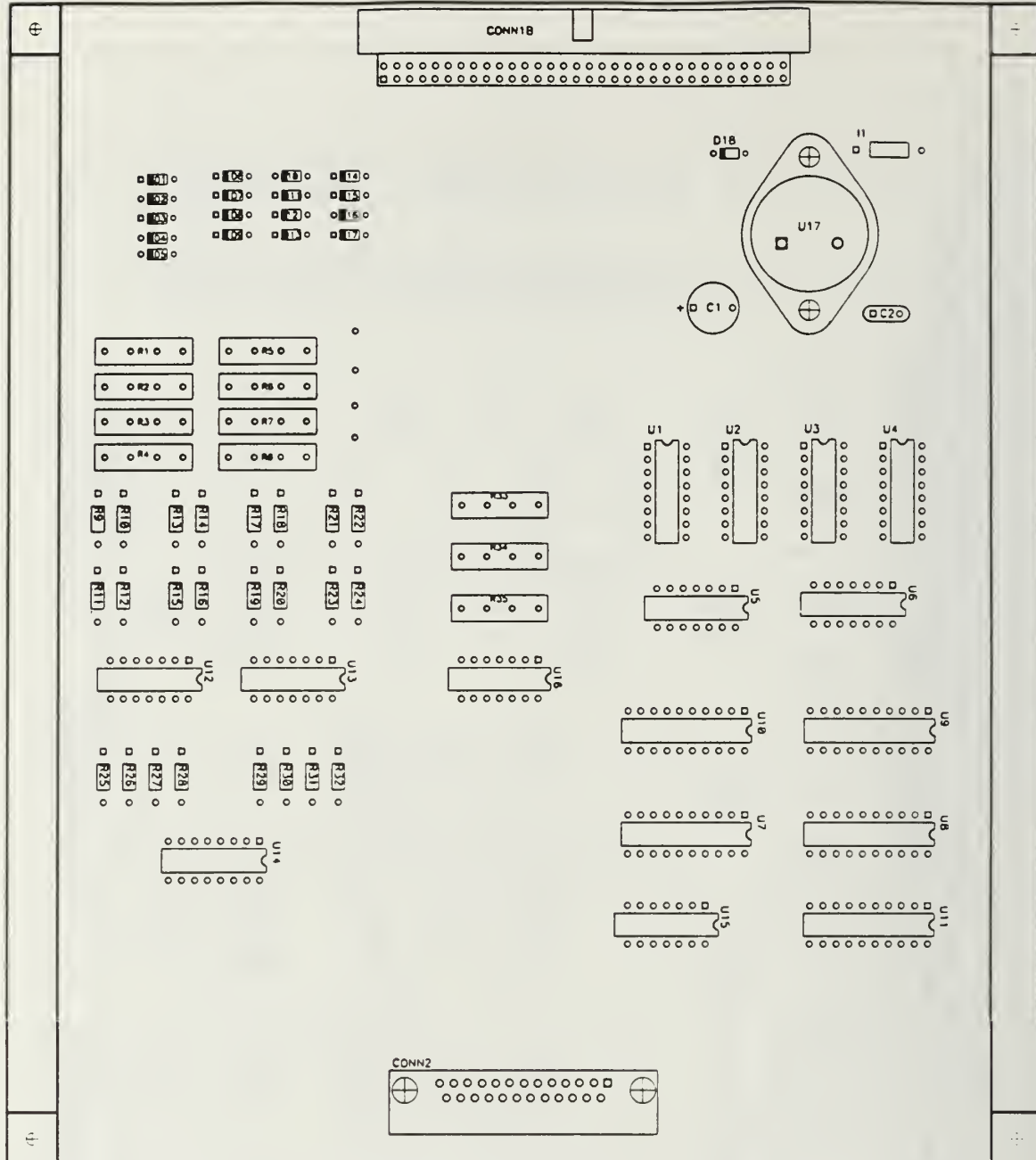
Component	Designator	Subcircuit	Duty cycle	Power Dissipation, Bus = 15V (Sunlit)	Power Dissipation, Bus = 12V (Eclipse)	X-Coord	Y-Coord
PMOSFET Gate Bias Resistor	R2C	CHARG Battery A Power Switch	30	0.000	0.000		
NMOSFET Gate Protection Resistor	R3C		30	0.003	0.003		
PMOSFET	T1C		30	0.014	0.021		
NMOSFET	T2C		30	0.000	0.000		
Pico Fuse	F1C		30	0.016	0.025		
Inductor	I1D	CHARG Battery A Power Switch	60	0.012	N/A	4.300	8.900
Transient Voltage Suppressor	TVS1D		~0		"	5.025	8.637
Ultra Fast Recovery Diode	UFR1D		~0		"	3.925	8.600
12v Zener Bi-Directional	D1D		~0		"	3.750	8.125
PMOSFET Gate Bias Resistor	R1D		60	0.002	"	5.125	7.250
PMOSFET Gate Bias Resistor	R2D		60	0.000	"	4.950	7.075
NMOSFET Gate Protection Resistor	R3D		60	0.003	0.003	3.750	7.575
PMOSFET	T1D		60	0.008	"	4.475	7.850
NMOSFET	T2D		60	0.000	"	3.875	7.000
Pico Fuse	F1D		60	0.002	"	5.250	8.175
Inductor	I1E	CHARG Battery B Power Switch	60	0.050	N/A	4.300	6.475
Transient Voltage Suppressor	TVS1E		~0		"	5.025	6.212
Ultra Fast Recovery Diode	UFR1E		~0		"	3.925	6.175
12v Zener Bi-Directional	D1E		~0		"	3.750	5.700
PMOSFET Gate Bias Resistor	R1E		60	0.002	"	5.125	4.825
PMOSFET Gate Bias Resistor	R2E		60	0.000	"	4.950	4.650
NMOSFET Gate Protection Resistor	R3E		60	0.003	0.003	3.750	5.150
PMOSFET	T1E		60	0.008	"	4.475	5.425
NMOSFET	T2E		60	0.000	"	3.875	4.575
Pico Fuse	F1E		60	0.050	"	5.250	5.650
Inductor	I1F	MUX A	30	0.006	0.009	8.400	8.875
Transient Voltage Suppressor	TVS1F		~0			7.297	9.450
Ultra Fast Recovery Diode	UFR1F		~0			8.125	9.225
12v Zener Bi-Directional	D1F		~0			7.175	8.550
PMOSFET Gate Bias Resistor	R1F		30	0.002	0.001	7.175	8.950
PMOSFET Gate Bias Resistor	R2F		30	0.000	0.000	7.400	8.950
NMOSFET Gate Protection Resistor	R3F		30	0.003	0.003	7.225	8.375
PMOSFET	T1F		30	0.003	0.004	7.775	9.050
PMOSFET	T1F2		30	0.003	0.004	6.850	9.050
NMOSFET	T2F		30	0.000	0.000	7.775	8.450
Pico Fuse	F1F		100	0.001	0.002	6.475	9.125



Component	Designator	Subcircuit	Duty cycle	Power Dissipation, Bus = 15V (Sunlit)	Power Dissipation, Bus = 12V (Eclipse)	X-Coord	Y-Coord
Inductor	I1G	MUX B	30	0.006	0.009	8.400	7.525
Transient Voltage Suppressor	TVS1G	"	~0			7.297	8.100
Ultra Fast Recovery Diode	UFR1G	"	~0			8.125	7.875
12v Zener Bi-Directional	D1G	"	~0			7.175	7.200
PMOSFET Gate Bias Resistor	R1G	"	30	0.002	0.001	7.175	7.600
PMOSFET Gate Bias Resistor	R2G	"	30	0.000	0.000	7.400	7.600
NMOSFET Gate Protection Resistor	R3G	"	30	0.003	0.003	7.225	7.025
PMOSFET	T1G	"	30	0.003	0.004	7.775	7.700
PMOSFET	T1G2	"	30	0.003	0.004	6.850	7.700
NMOSFET	T2G	"	30	0.000	0.000	7.775	7.100
Pico Fuse	F1G	"	100	0.001	0.009	6.475	7.775
Inductor	I1H	MASS A	30	0.001	0.002	8.400	6.175
Transient Voltage Suppressor	TVS1H	"	~0			7.297	6.750
Ultra Fast Recovery Diode	UFR1H	"	~0			8.125	6.525
12v Zener Bi-Directional	D1H	"	~0			7.175	5.850
PMOSFET Gate Bias Resistor	R1H	"	30	0.002	0.001	7.175	6.250
PMOSFET Gate Bias Resistor	R2H	"	30	0.000	0.000	7.400	6.250
NMOSFET Gate Protection Resistor	R3H	"	30	0.003	0.003	7.225	5.675
PMOSFET	T1H	"	30	0.001	0.001	7.775	6.350
PMOSFET	T1H2	"	30	0.001	0.001	6.850	6.350
NMOSFET	T2H	"	30	0.000	0.000	7.775	5.750
Pico Fuse	F1H	"	100	0.000	0.000	6.475	6.425
Inductor	I1I	MASS B	30	0.001	0.002	8.400	4.825
Transient Voltage Suppressor	TVS1I	"	~0			7.297	5.400
Ultra Fast Recovery Diode	UFR1I	"	~0			8.125	5.175
12v Zener Bi-Directional	D1I	"	~0			7.175	4.500
PMOSFET Gate Bias Resistor	R1I	"	30	0.002	0.001	7.175	4.900
PMOSFET Gate Bias Resistor	R2I	"	30	0.000	0.000	7.400	4.900
NMOSFET Gate Protection Resistor	R3I	"	30	0.003	0.003	7.225	4.325
PMOSFET	T1I	"	30	0.001	0.001	7.775	5.000
PMOSFET	T1I2	"	30	0.001	0.001	6.850	5.000
NMOSFET	T2I	"	30	0.000	0.000	7.775	4.400
Pico Fuse	F1I	"	100	0.000	0.000	6.475	5.075
Inductor	I1J	TRICKLE A	~0			8.400	3.475
Transient Voltage Suppressor	TVS1J	"	~0			7.297	4.050

Component	Designator	Subcircuit	Duty cycle	Power Dissipation, Bus = 15V (Sunlit)	Power Dissipation, Bus = 12V (Eclipse)	X-Coord	Y-Coord
Ultra Fast Recovery Diode	UFR1J	"	~0			8.125	3.825
12v Zener Bi-Directional	D1J	"	~0			7.175	3.150
PMOSFET Gate Bias Resistor	R1J	"	~0			7.175	3.550
PMOSFET Gate Bias Resistor	R2J	"	~0			7.400	3.550
NMOSFET Gate Protection Resistor	R3J	"	~0			7.225	2.975
PMOSFET	T1J	"	~0			7.775	3.650
PMOSFET	T1J2	"	~0			6.850	3.650
NMOSFET	T2J	"	~0			7.775	3.050
Pico Fuse	F1J	"	~0			6.475	3.725
Inductor	I1K	TRICKLE B	~0			8.400	2.100
Transient Voltage Suppressor	TVS1K	"	~0			7.297	2.675
Ultra Fast Recovery Diode	UFR1K	"	~0			8.125	2.450
12v Zener Bi-Directional	D1K	"	~0			7.175	1.775
PMOSFET Gate Bias Resistor	R1K	"	~0			7.175	2.175
PMOSFET Gate Bias Resistor	R2K	"	~0			7.400	2.175
PMOSFET Gate Bias Resistor	R3K	"	~0			7.225	1.600
PMOSFET	T1K	"	~0			7.775	2.275
PMOSFET	T1K2	"	~0			6.850	2.275
NMOSFET	T2K	"	~0			7.775	1.675
Pico Fuse	F1K	"	~0			6.475	2.350
NMOSFET	T3A	Discharge Battery A				5.750	5.300
NMOSFET	T3B	Discharge Battery B				5.775	3.650
LM150	IS1A	Constant Current Source				3.975	3.092
LM150	IS1B	Constant Current Source				5.225	3.092
			Total Power	#REF!	0.280W		







## APPENDIX K. ITAS THERMAL MASS/DISSIPATIONS

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
1	901	30	-1.870	0	EPS HOUSING WALL
2	902	30	-.4179	0	EPS HOUSING WALL
3	903	30	-.4179	0	EPS HOUSING WALL
4	904	30	-.4179	0	EPS HOUSING WALL
5	905	30	.4179	0	EPS HOUSING WALL
6	906	30	-10.15	0	BOTTOM EPS HOUSING
7	907	30	-1.871	0	EPS HOUSING WALL
8	908	30	-.4179	0	EPS HOUSING WALL
9	909	30	-.4179	0	EPS HOUSING WALL
10	910	30	-.4179	0	EPS HOUSING WALL
11	911	30	-.4179	0	EPS HOUSING WALL
12	912	30	-10.02	0	EPS HOUSING WALL
13	913	30	-6.259	0	EQUIPMENT PLATE TO BOTTOM EPS
14	921	30	-.2664	0	BOTTOM RAIL (+Y)
15	922	30	-.3995	0	MIDDLE RAIL (+Y)
16	923	30	-.2120	0	TOP RAIL (+Y)
17	924	30	-.2664	0	BOTTOM RAIL (-Y)
18	925	30	-.3995	0	MIDDLE RAIL (-Y)

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End

SHIFT-F1Import Column Shift-F5Del/Pur

F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
19	926	30	-.2120	0	TOP RAIL (-Y)
20	601	30	-.0043	0	TOP PCB THERMAL LAYER
21	602	30	-.0058	0	
22	603	30	-.0016	0	
23	604	30	-.0062	0	
24	605	30	-.0016	0	
25	606	30	-.0085	0	
26	607	30	-.0051	0	
27	608	30	-.0070	0	
28	609	30	-.0019	0	
29	610	30	-.0075	0	
30	611	30	-.0019	0	
31	612	30	-.0103	0	
32	613	30	-.0019	0	
33	614	30	-.0015	0	
34	615	30	-.0015	0	
35	616	30	-.0015	0	
36	617	30	-.0015	0	

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End

SHIFT-F1Import Column Shift-F5Del/Pur

F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search



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electri:Copy=====ITAS Node Data Entry For Thermal Analysis=====ESC:Quit
□
□ SEQN      NodeNo      Temp-C      ThrMass      Dissip      Comment
□ 73        507         30          -.0528        0          TOP PCB BOTTOM POLY LAYER
□ 74        508         30          -.0720        0          TOP PCB BOTTOM POLY LAYER
□ 75        509         30          -.0192        0          TOP PCB BOTTOM POLY LAYER
□ 76        510         30          -.0768        0          TOP PCB BOTTOM POLY LAYER
□ 77        511         30          -.0192        0          TOP PCB BOTTOM POLY LAYER
□ 78        512         30          -.1056        0          TOP PCB BOTTOM POLY LAYER
□ 79        513         30          -.0190        0          TOP PCB BOTTOM POLY LAYER
□ 80        514         30          -.0149        0          TOP PCB BOTTOM POLY LAYER
□ 81        515         30          -.0149        0          TOP PCB BOTTOM POLY LAYER
□ 82        516         30          -.0149        0          TOP PCB BOTTOM POLY LAYER
□ 83        517         30          -.0149        0          TOP PCB BOTTOM POLY LAYER
□ 84        518         30          -.0190        0          TOP PCB BOTTOM POLY LAYER
□ 85        519         30          -.0248        0          TOP PCB BOTTOM POLY LAYER
□ 86        520         30          -.0195        0          TOP PCB BOTTOM POLY LAYER
□ 87        521         30          -.0195        0          TOP PCB BOTTOM POLY LAYER
□ 88        522         30          -.0195        0          TOP PCB BOTTOM POLY LAYER
□ 89        523         30          -.0195        0          TOP PCB BOTTOM POLY LAYER
□ 90        524         30          -.0248        0          TOP PCB BOTTOM POLY LAYER

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CTRL-F1Import ITAS_NC      UDC Allowed      PgDn PgUp Home End
SHFT-F1Import Column      Shift-F5Del/Pur
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

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ëèCtrl:Copyë=====ITAS Node Data Entry For Thermal Analysis =====ESC:Quitë

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□
□ SEQN      NodeNo      Temp-C      ThrMass      Dissip      Comment
□ 91        525         30          -.0161        0          TOP PCB BOTTOM POLY LAYER
□ 92        526         30          -.0161        0          TOP PCB BOTTOM POLY LAYER
□ 93        527         30          -.0161        0          TOP PCB BOTTOM POLY LAYER
□ 94        528         30          -.0161        0          TOP PCB BOTTOM POLY LAYER
□ 95        529         30          -.0161        0          TOP PCB BOTTOM POLY LAYER
□ 96        530         30          -.0205        0          TOP PCB BOTTOM POLY LAYER
□ 97        1501        30          -.1069        0          BOTTOM PCB BOTTOM POLY LAYER
□ 98        1502        30          -.0627        0          BOTTOM PCB BOTTOM POLY LAYER
□ 99        1503        30          -.0451        0          BOTTOM PCB BOTTOM POLY LAYER
□ 100       1504        30          -.0526        0          BOTTOM PCB BOTTOM POLY LAYER
□ 101       1505        30          -.0200        0          BOTTOM PCB BOTTOM POLY LAYER
□ 102       1506        30          -.1002        0          BOTTOM PCB BOTTOM POLY LAYER
□ 103       1507        30          -.0313        0          BOTTOM PCB BOTTOM POLY LAYER
□ 104       1508        30          -.0226        0          BOTTOM PCB BOTTOM POLY LAYER
□ 105       1509        30          -.0288        0          BOTTOM PCB BOTTOM POLY LAYER
□ 106       1510        30          -.0075        0          BOTTOM PCB BOTTOM POLY LAYER
□ 107       1511        30          -.0100        0          BOTTOM PCB BOTTOM POLY LAYER
□ 108       1512        30          -.0100        0          BOTTOM PCB BOTTOM POLY LAYER

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æ=====
CTRL-F1Import ITAS_NC      UDC Allowed      PgDn PgUp Home End
SHFT-F1Import Column      Shift-F5Del/Pur
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

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Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
109	1513	30	-.0501	0	BOTTOM PCB BOTTOM POLY LAYER
110	1514	30	-.0731	0	BOTTOM PCB BOTTOM POLY LAYER
111	1515	30	-.1140	0	BOTTOM PCB BOTTOM POLY LAYER
112	1516	30	-.1403	0	BOTTOM PCB BOTTOM POLY LAYER
113	1517	30	-.0468	0	BOTTOM PCB BOTTOM POLY LAYER
114	401	30	-.0043	0	TOP PCB THERMAL COPPER LAYER
115	402	30	-.0058	0	TOP PCB THERMAL COPPER LAYER
116	403	30	-.0016	0	TOP PCB THERMAL COPPER LAYER
117	404	30	-.0062	0	TOP PCB THERMAL COPPER LAYER
118	405	30	-.0016	0	TOP PCB THERMAL COPPER LAYER
119	406	30	-.0085	0	TOP PCB THERMAL COPPER LAYER
120	407	30	-.0051	0	TOP PCB THERMAL COPPER LAYER
121	408	30	-.0071	0	TOP PCB THERMAL COPPER LAYER
122	409	30	-.0019	0	TOP PCB THERMAL COPPER LAYER
123	410	30	-.0075	0	TOP PCB THERMAL COPPER LAYER
124	411	30	-.0019	0	TOP PCB THERMAL COPPER LAYER
125	412	30	-.0103	0	TOP PCB THERMAL COPPER LAYER
126	413	30	-.0019	0	TOP PCB THERMAL COPPER LAYER

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
 SHFT-F1Import Column Shift-F5Del/Pur  
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
127	414	30	-.0015	0	TOP PCB THERMAL COPPER LAYER
128	415	30	-.0015	0	TOP PCB THERMAL COPPER LAYER
129	416	30	-.0015	0	TOP PCB THERMAL COPPER LAYER
130	417	30	-.0015	0	TOP PCB THERMAL COPPER LAYER
131	418	30	-.0019	0	TOP PCB THERMAL COPPER LAYER
132	419	30	-.0024	0	TOP PCB THERMAL COPPER LAYER
133	420	30	-.0019	0	TOP PCB THERMAL COPPER LAYER
134	421	30	-.0019	0	TOP PCB THERMAL COPPER LAYER
135	422	30	-.0019	0	TOP PCB THERMAL COPPER LAYER
136	423	30	-.0019	0	TOP PCB THERMAL COPPER LAYER
137	424	30	-.0024	0	TOP PCB THERMAL COPPER LAYER
138	425	30	-.0016	0	TOP PCB THERMAL COPPER LAYER
139	426	30	-.0016	0	TOP PCB THERMAL COPPER LAYER
140	427	30	-.0016	0	TOP PCB THERMAL COPPER LAYER
141	428	30	-.0016	0	TOP PCB THERMAL COPPER LAYER
142	429	30	-.0016	0	TOP PCB THERMAL COPPER LAYER
143	430	30	-.0020	0	TOP PCB THERMAL COPPER LAYER
144	1401	30	-.0104	0	BOTTOM PCB GROUND (COPPER) LAYER

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
 SHFT-F1Import Column Shift-F5Del/Pur  
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search



Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
145	1402	30	-.0061	0	BOTTOM PCB GROUND (COPPER) LAYER
146	1403	30	-.0044	0	BOTTOM PCB GROUND (COPPER) LAYER
147	1404	30	-.0051	0	BOTTOM PCB GROUND (COPPER) LAYER
148	1405	30	-.0020	0	BOTTOM PCB GROUND (COPPER) LAYER
149	1406	30	-.0098	0	BOTTOM PCB GROUND (COPPER) LAYER
150	1407	30	-.0031	0	BOTTOM PCB GROUND (COPPER) LAYER
151	1408	30	-.0022	0	BOTTOM PCB GROUND (COPPER) LAYER
152	1409	30	-.0028	0	BOTTOM PCB GROUND (COPPER) LAYER
153	1410	30	-.0007	0	BOTTOM PCB GROUND (COPPER) LAYER
154	1411	30	-.0010	0	BOTTOM PCB GROUND (COPPER) LAYER
155	1412	30	-.0010	0	BOTTOM PCB GROUND (COPPER) LAYER
156	1413	30	-.0049	0	BOTTOM PCB GROUND (COPPER) LAYER
157	1414	30	-.0071	0	BOTTOM PCB GROUND (COPPER) LAYER
158	1415	30	-.0111	0	BOTTOM PCB GROUND (COPPER) LAYER
159	1416	30	-.0137	0	BOTTOM PCB GROUND (COPPER) LAYER
160	1417	30	-.0046	0	BOTTOM PCB GROUND (COPPER) LAYER
161	301	30	-.0436	0	TOP PCB MIDDLE POLY LAYER
162	302	30	-.0595	0	TOP PCB MIDDLE POLY LAYER

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
SHIFT-F1Import Column Shift-F5Del/Pur  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
163	303	30	-.0159	0	TOP PCB MIDDLE POLY LAYER
164	304	30	-.0635	0	TOP PCB MIDDLE POLY LAYER
165	305	30	-.0159	0	TOP PCB MIDDLE POLY LAYER
166	306	30	-.0873	0	TOP PCB MIDDLE POLY LAYER
167	307	30	-.0528	0	TOP PCB MIDDLE POLY LAYER
168	308	30	-.0720	0	TOP PCB MIDDLE POLY LAYER
169	309	30	-.0192	0	TOP PCB MIDDLE POLY LAYER
170	310	30	-.0768	0	TOP PCB MIDDLE POLY LAYER
171	311	30	-.0192	0	TOP PCB MIDDLE POLY LAYER
172	312	30	-.1056	0	TOP PCB MIDDLE POLY LAYER
173	313	30	-.0190	0	TOP PCB MIDDLE POLY LAYER
174	314	30	-.0149	0	TOP PCB MIDDLE POLY LAYER
175	315	30	-.0149	0	TOP PCB MIDDLE POLY LAYER
176	316	30	-.0149	0	TOP PCB MIDDLE POLY LAYER
177	317	30	-.0149	0	TOP PCB MIDDLE POLY LAYER
178	318	30	-.0190	0	TOP PCB MIDDLE POLY LAYER
179	319	30	-.0248	0	TOP PCB MIDDLE POLY LAYER
180	320	30	-.0195	0	TOP PCB MIDDLE POLY LAYER

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
SHIFT-F1Import Column Shift-F5Del/Pur  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search



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CTRL-F1Import ITAS_NC      UDC Allowed      PgDn PgUp Home End
SHFT-F1Import Column      Shift-F5Del/Pur
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

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ëëCtrl:Copyëëëëëë ITAS Node Data Entry For Thermal Analysis ëëëëëëëëESC:Quitëë
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SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
199	1309	30	-.0288	0	BOTTOM PCB MIDDLE POLY LAYER
200	1310	30	-.0075	0	BOTTOM PCB MIDDLE POLY LAYER
201	1311	30	-.0100	0	BOTTOM PCB MIDDLE POLY LAYER
202	1312	30	-.0100	0	BOTTOM PCB MIDDLE POLY LAYER
203	1313	30	-.0501	0	BOTTOM PCB MIDDLE POLY LAYER
204	1314	30	-.0731	0	BOTTOM PCB MIDDLE POLY LAYER
205	1315	30	-.1140	0	BOTTOM PCB MIDDLE POLY LAYER
206	1316	30	-.1403	0	BOTTOM PCB MIDDLE POLY LAYER
207	1317	30	-.0468	0	BOTTOM PCB MIDDLE POLY LAYER
208	201	30	-.0043	0	TOP PCB TOP COPPER LAYER
209	202	30	-.0058	0	TOP PCB TOP COPPER LAYER
210	203	30	-.0016	0	TOP PCB TOP COPPER LAYER
211	204	30	-.0062	0	TOP PCB TOP COPPER LAYER
212	205	30	-.0016	0	TOP PCB TOP COPPER LAYER
213	206	30	-.0085	0	TOP PCB TOP COPPER LAYER
214	207	30	-.0051	0	TOP PCB TOP COPPER LAYER
215	208	30	-.0070	0	TOP PCB TOP COPPER LAYER
216	209	30	-.0019	0	TOP PCB TOP COPPER LAYER

```

CTRL-F1Import ITAS_NC      UDC Allowed                      PgDn PgUp Home End
SHIFT-F1Import Column          Shift-F5Del/Pur
F1Save/Purge    F2Help F3AutoGen F4Purge F5Delete   F7Mark/UnMark F10Search

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Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
217	210	30	-.0075	0	TOP PCB TOP COPPER LAYER
218	211	30	-.0019	0	TOP PCB TOP COPPER LAYER
219	212	30	-.0103	0	TOP PCB TOP COPPER LAYER
220	213	30	-.0019	0	TOP PCB TOP COPPER LAYER
221	214	30	-.0015	0	TOP PCB TOP COPPER LAYER
222	215	30	-.0015	0	TOP PCB TOP COPPER LAYER
223	216	30	-.0015	0	TOP PCB TOP COPPER LAYER
224	217	30	-.0015	0	TOP PCB TOP COPPER LAYER
225	218	30	-.0187	0	TOP PCB TOP COPPER LAYER
226	219	30	-.0024	0	TOP PCB TOP COPPER LAYER
227	220	30	-.0019	0	TOP PCB TOP COPPER LAYER
228	221	30	-.0019	0	TOP PCB TOP COPPER LAYER
229	222	30	-.0019	0	TOP PCB TOP COPPER LAYER
230	223	30	-.0019	0	TOP PCB TOP COPPER LAYER
231	224	30	-.0024	0	TOP PCB TOP COPPER LAYER
232	225	30	-.0016	0	TOP PCB TOP COPPER LAYER
233	226	30	-.0016	0	TOP PCB TOP COPPER LAYER
234	227	30	-.0016	0	TOP PCB TOP COPPER LAYER

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
SHIFT-F1Import Column Shift-F5Del/Pur  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
235	228	30	-.0016	0	TOP PCB TOP COPPER LAYER
236	229	30	-.0016	0	TOP PCB TOP COPPER LAYER
237	230	30	-.0020	0	TOP PCB TOP COPPER LAYER
238	1201	30	-.0104	0	BOTTOM PCB TOP COPPER LAYER
239	1202	30	-.0061	0	BOTTOM PCB TOP COPPER LAYER
240	1203	30	-.0044	0	BOTTOM PCB TOP COPPER LAYER
241	1204	30	-.0051	0	BOTTOM PCB TOP COPPER LAYER
242	1205	30	-.0020	0	BOTTOM PCB TOP COPPER LAYER
243	1206	30	-.0098	0	BOTTOM PCB TOP COPPER LAYER
244	1207	30	-.0031	0	BOTTOM PCB TOP COPPER LAYER
245	1208	30	-.0022	0	BOTTOM PCB TOP COPPER LAYER
246	1209	30	-.0028	0	BOTTOM PCB TOP COPPER LAYER
247	1210	30	-.0007	0	BOTTOM PCB TOP COPPER LAYER
248	1211	30	-.0010	0	BOTTOM PCB TOP COPPER LAYER
249	1212	30	-.0010	0	BOTTOM PCB TOP COPPER LAYER
250	1213	30	-.0049	0	BOTTOM PCB TOP COPPER LAYER
251	1214	30	-.0071	0	BOTTOM PCB TOP COPPER LAYER
252	1215	30	-.0111	0	BOTTOM PCB TOP COPPER LAYER

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
SHIFT-F1Import Column Shift-F5Del/Pur  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
253	1216	30	-.0137	0	BOTTOM PCB TOP COPPER LAYER
254	1217	30	-.0046	0	BOTTOM PCB TOP COPPER LAYER
255	101	30	-.0436	0	TOP PCB TOP POLY LAYER
256	102	30	-.0595	0	TOP PCB TOP POLY LAYER
257	103	30	-.0159	0	TOP PCB TOP POLY LAYER
258	104	30	-.0635	0	TOP PCB TOP POLY LAYER
259	105	30	-.0159	0	TOP PCB TOP POLY LAYER
260	106	30	-.0873	0	TOP PCB TOP POLY LAYER
261	107	30	-.0528	0	TOP PCB TOP POLY LAYER
262	108	30	-.0720	0	TOP PCB TOP POLY LAYER
263	109	30	-.0192	0	TOP PCB TOP POLY LAYER
264	110	30	-.0768	0	TOP PCB TOP POLY LAYER
265	111	30	-.0192	0	TOP PCB TOP POLY LAYER
266	112	30	-.1056	0	TOP PCB TOP POLY LAYER
267	113	30	-.0190	0	TOP PCB TOP POLY LAYER
268	114	30	-.0149	0	TOP PCB TOP POLY LAYER
269	115	30	-.0149	0	TOP PCB TOP POLY LAYER
270	116	30	-.0149	0	TOP PCB TOP POLY LAYER

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

Ctrl-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
Shift-F1Import Column Shift-F5Del/Pur  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
271	117	30	-.0149	0	TOP PCB TOP POLY LAYER
272	118	30	-.0190	0	TOP PCB TOP POLY LAYER
273	119	30	-.0248	0	TOP PCB TOP POLY LAYER
274	120	30	-.0195	0	TOP PCB TOP POLY LAYER
275	121	30	-.0195	0	TOP PCB TOP POLY LAYER
276	122	30	-.0195	0	TOP PCB TOP POLY LAYER
277	123	30	-.0195	0	TOP PCB TOP POLY LAYER
278	124	30	-.0248	0	TOP PCB TOP POLY LAYER
279	125	30	-.0161	0	TOP PCB TOP POLY LAYER
280	126	30	-.0161	0	TOP PCB TOP POLY LAYER
281	127	30	-.0161	0	TOP PCB TOP POLY LAYER
282	128	30	-.0161	0	TOP PCB TOP POLY LAYER
283	129	30	-.0161	0	TOP PCB TOP POLY LAYER
284	130	30	-.0205	0	TOP PCB TOP POLY LAYER
285	1101	30	-.1069	0	BOTTOM PCB TOP POLY LAYER
286	1102	30	-.0627	0	BOTTOM PCB TOP POLY LAYER
287	1103	30	-.0451	0	BOTTOM PCB TOP POLY LAYER
288	1104	30	-.0526	0	BOTTOM PCB TOP POLY LAYER

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

Ctrl-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
Shift-F1Import Column Shift-F5Del/Pur  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search





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Ctrl:Copy===== ITAS Node Data Entry For Thermal Analysis =====ESC:Quit
SEQN  NodeNo  Temp-C  ThrMass  Dissip  Comment
343    2081    30      -.0004   .015    PIN THROUGH 3.08 POLY LAYERS
344    2083    30      -.0004   0       PIN THROUGH 3.08 POLY LAYERS
345    2085    30      -.0004   0       PIN THROUGH 3.08 POLY LAYERS
346    2082    30      -.0001   0       PIN THROUGH 3.08 COPPER LAYERS
347    2084    30      -.0001   0       PIN THROUGH 3.08 COPPER LAYERS
348    2086    30      -.0001   0       PIN THROUGH 3.08 COPPER LAYERS
349    2091    30      -.0001   .05     PIN THROUGH 3.09 POLY LAYERS
350    2093    30      -.0001   0       PIN THROUGH 3.09 POLY LAYERS
351    2095    30      -.0001   0       PIN THROUGH 3.09 POLY LAYERS
352    2092    30      -.0001   0       PIN THROUGH 3.09 COPPER LAYERS
353    2094    30      -.0001   0       PIN THROUGH 3.09 COPPER LAYERS
354    2096    30      -.0001   0       PIN THROUGH 3.09 COPPER LAYERS
355    2101    30      -.0004   .015    PIN THROUGH 3.10 POLY LAYERS
356    2103    30      -.0004   0       PIN THROUGH 3.10 POLY LAYERS
357    2105    30      -.0004   0       PIN THROUGH 3.10 POLY LAYERS
358    2102    30      -.0001   0       PIN THROUGH 3.10 COPPER LAYERS
359    2104    30      -.0001   0       PIN THROUGH 3.10 COPPER LAYERS
360    2106    30      -.0001   0       PIN THROUGH 3.10 COPPER LAYERS
=====
CTRL-F1Import ITAS_NC      UDC Allowed      PgDn PgUp Home End
SHIFT-F1Import Column      Shift-F5Del/Pur
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```



Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
361	2111	30	-.0001	0	PIN THROUGH 3.11 POLY LAYERS
362	2113	30	-.0001	0	PIN THROUGH 3.11 POLY LAYERS
363	2115	30	-.0001	0	PIN THROUGH 3.11 POLY LAYERS
364	2112	30	-.0001	0	PIN THROUGH 3.12 COPPER LAYERS
365	2114	30	-.0001	0	PIN THROUGH 3.12 COPPER LAYERS
366	2116	30	-.0001	0	PIN THROUGH 3.12 COPPER LAYERS
367	2121	30	-.0002	0	PIN THROUGH 3.12 POLY LAYER
368	2123	30	-.0002	0	PIN THROUGH 3.12 POLY LAYER
369	2125	30	-.0002	0	PIN THROUGH 3.12 POLY LAYER
370	2122	30	-.0001	0	PIN THROUGH 3.12 COPPER LAYERS
371	2131	30	-.0001	.004	PIN THROUGH 2.01 POLY LAYER
372	2133	30	-.0001	0	PIN THROUGH 2.01 POLY LAYER
373	2135	30	-.0001	0	PIN THROUGH 2.01 POLY LAYER
374	2132	30	-.0001	0	PIN THROUGH 2.01 COPPER LAYERS
375	2134	30	-.0001	0	PIN THROUGH 2.01 COPPER LAYERS
376	2136	30	-.0001	0	PIN THROUGH 2.01 COPPER LAYERS
377	2141	30	-.0001	.004	PIN THROUGH 2.02 POLY LAYERS
378	2143	30	-.0001	0	PIN THROUGH 2.02 POLY LAYERS

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
SHIFT-F1Import Column Shift-F5Del/Pur  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
379	2145	30	-.0001	0	PIN THROUGH 2.02 POLY LAYERS
380	2142	30	-.0001	0	PIN THROUGH 2.02 COPPER LAYERS
381	2144	30	-.0001	0	PIN THROUGH 2.02 COPPER LAYERS
382	2146	30	-.0001	0	PIN THROUGH 2.02 COPPER LAYERS
383	2151	30	-.0001	.001	PIN THROUGH 2.03 POLY LAYER
384	2153	30	-.0001	0	PIN THROUGH 2.03 POLY LAYER
385	2155	30	-.0001	0	PIN THROUGH 2.03 POLY LAYER
386	2152	30	-.0001	0	PIN THROUGH 2.03 COPPER LAYERS
387	2154	30	-.0001	0	PIN THROUGH 2.03 COPPER LAYERS
388	2156	30	-.0001	0	PIN THROUGH 2.03 COPPER LAYERS
389	2161	30	-.0001	.001	PIN THROUGH 2.04 POLY LAYER
390	2163	30	-.0001	0	PIN THROUGH 2.04 POLY LAYER
391	2165	30	-.0001	0	PIN THROUGH 2.04 POLY LAYER
392	2162	30	-.0001	0	PIN THROUGH 2.04 COPPER LAYERS
393	2164	30	-.0001	0	PIN THROUGH 2.04 COPPER LAYERS
394	2166	30	-.0001	0	PIN THROUGH 2.04 COPPER LAYERS
395	2171	30	-.0001	0	PIN THROUGH 2.05 POLY LAYERS
396	2173	30	-.0001	0	PIN THROUGH 2.05 POLY LAYERS

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
SHIFT-F1Import Column Shift-F5Del/Pur  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

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ëëCtrl:Copyëëëëëë ITAS Node Data Entry For Thermal Analysis ëëëëëëëëESC:Quitëë

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Ctrl:CopyITAS Node Data Entry For Thermal AnalysisESC:Quit
SEQN NodeNo Temp-C ThrMass Dissip Comment
469 2295 30 -.0001 0 PIN THROUGH 2.17 POLY LAYERS
470 2292 30 -.0001 0 PIN THROUGH 2.17 COPPER LAYERS
471 2294 30 -.0001 0 PIN THROUGH 2.17 COPPER LAYERS
472 2296 30 -.0001 0 PIN THROUGH 2.17 COPPER LAYERS
473 2301 30 -.0001 0 PIN THROUGH 2.18 POLY LAYERS
474 2303 30 -.0001 0 PIN THROUGH 2.18 POLY LAYERS
475 2305 30 -.0001 0 PIN THROUGH 2.18 POLY LAYERS
476 2302 30 -.0001 0 PIN THROUGH 2.18 COPPER LAYERS
477 2304 30 -.0001 0 PIN THROUGH 2.18 COPPER LAYERS
478 2306 30 -.0001 0 PIN THROUGH 2.18 COPPER LAYERS
479 3011 30 -.0011 0 PIN THROUGH 4.00 POLY LAYERS
480 3013 30 -.0011 0 PIN THROUGH 4.00 POLY LAYERS
481 3015 30 -.0011 0 PIN THROUGH 4.00 POLY LAYERS
482 3012 30 -.0001 0 PIN THROUGH 4.00 COPPER LAYERS
483 3014 30 -.0001 0 PIN THROUGH 4.00 COPPER LAYERS
484 3016 30 -.0001 0 PIN THROUGH 4.00 COPPER LAYERS
485 3021 30 -.0006 .113 PIN THROUGH 5.01 POLY LAYERS
486 3023 30 -.0006 0 PIN THROUGH 5.01 POLY LAYERS

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Ctrl-F1Import ITAS_NC UDC Allowed PgDn PgUp Home End
SHFT-F1Import Column Shift-F5Del/Pur
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

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Ctrl:CopyITAS Node Data Entry For Thermal AnalysisESC:Quit

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SEQN NodeNo Temp-C ThrMass Dissip Comment
487 3025 30 -.0006 0 PIN THROUGH 5.01 POLY LAYERS
488 3022 30 -.0001 0 PIN THROUGH 5.01 COPPER LAYERS
489 3024 30 -.0001 0 PIN THROUGH 5.01 COPPER LAYERS
490 3026 30 -.0001 0 PIN THROUGH 5.01 COPPER LAYERS
491 3031 30 -.0006 .036 PIN THROUGH 5.02 POLY LAYERS
492 3033 30 -.0006 0 PIN THROUGH 5.02 POLY LAYERS
493 3035 30 -.0006 0 PIN THROUGH 5.02 POLY LAYERS
494 3032 30 -.0001 0 PIN THROUGH 5.02 COPPER LAYERS
495 3034 30 -.0001 0 PIN THROUGH 5.02 COPPER LAYERS
496 3036 30 -.0001 0 PIN THROUGH 5.02 COPPER LAYERS
497 3041 30 -.0002 0 PIN THROUGH 5.03 POLY LAYERS
498 3043 30 -.0002 0 PIN THROUGH 5.03 POLY LAYERS
499 3045 30 -.0002 0 PIN THROUGH 5.03 POLY LAYERS
500 3042 30 -.0001 0 PIN THROUGH 5.03 COPPER LAYERS
501 3044 30 -.0001 0 PIN THROUGH 5.03 COPPER LAYERS
502 3046 30 -.0001 0 PIN THROUGH 5.03 COPPER LAYERS
503 3051 30 -.0005 .05 PIN THROUGH 5.04 POLY LAYERS
504 3053 30 -.0005 0 PIN THROUGH 5.04 POLY LAYERS

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Ctrl-F1Import ITAS_NC UDC Allowed PgDn PgUp Home End
SHFT-F1Import Column Shift-F5Del/Pur
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

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Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
505	3055	30	-.0005	0	PIN THROUGH 5.04 POLY LAYERS
506	3052	30	-.0001	0	PIN THROUGH 5.04 COPPER LAYERS
507	3054	30	-.0001	0	PIN THROUGH 5.04 COPPER LAYERS
508	3056	30	-.0001	0	PIN THROUGH 5.04 COPPER LAYERS
509	3061	30	-.0006	.025	PIN THROUGH 5.05 POLY LAYERS
510	3063	30	-.0006	0	PIN THROUGH 5.05 POLY LAYERS
511	3065	30	-.0006	0	PIN THROUGH 5.05 POLY LAYERS
512	3062	30	-.0006	0	PIN THROUGH 5.05 COPPER LAYERS
513	3064	30	-.0001	0	PIN THROUGH 5.05 COPPER LAYERS
514	3066	30	-.0001	0	PIN THROUGH 5.05 COPPER LAYERS
515	3091	30	-.0001	.1	PIN THROUGH 6.03 POLY LAYERS
516	3093	30	-.0001	0	PIN THROUGH 6.03 POLY LAYERS
517	3095	30	-.0001	0	PIN THROUGH 6.03 POLY LAYERS
518	3092	30	-.0001	0	PIN THROUGH 6.03 COPPER LAYERS
519	3094	30	-.0001	0	PIN THROUGH 6.03 COPPER LAYERS
520	3096	30	-.0001	0	PIN THROUGH 6.03 COPPER LAYERS
521	3101	30	-.0001	.125	PIN THROUGH 6.04 POLY LAYERS
522	3103	30	-.0001	0	PIN THROUGH 6.04 POLY LAYERS

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
SHIFT-F1Import Column Shift-F5Del/Pur  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
523	3105	30	-.0001	0	PIN THROUGH 6.04 POLY LAYERS
524	3102	30	-.0001	0	PIN THROUGH 6.04 COPPER LAYERS
525	3104	30	-.0001	0	PIN THROUGH 6.04 COPPER LAYERS
526	3106	30	-.0001	0	PIN THROUGH 6.04 COPPER LAYERS
527	3111	30	-.0001	.025	PIN THROUGH 6.05 POLY LAYERS
528	3113	30	-.0001	0	PIN THROUGH 6.05 POLY LAYERS
529	3115	30	-.0001	0	PIN THROUGH 6.05 POLY LAYERS
530	3112	30	-.0001	0	PIN THROUGH 6.05 COPPER LAYER
531	3114	30	-.0001	0	PIN THROUGH 6.05 COPPER LAYER
532	3116	30	-.0001	0	PIN THROUGH 6.05 COPPER LAYER
533	3121	30	-.0003	.025	PIN THROUGH 6.06 POLY LAYERS
534	3123	30	-.0003	0	PIN THROUGH 6.06 POLY LAYERS
535	3125	30	-.0003	0	PIN THROUGH 6.06 POLY LAYERS
536	3122	30	-.0001	0	PIN THROUGH 6.06 COPPER LAYERS
537	3124	30	-.0001	0	PIN THROUGH 6.06 COPPER LAYERS
538	3126	30	-.0001	0	PIN THROUGH 6.06 COPPER LAYERS
539	3141	30	-.0002	.375	PIN THROUGH 7.01 POLY LAYERS
540	3143	30	-.0002	0	PIN THROUGH 7.01 POLY LAYERS

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
SHIFT-F1Import Column Shift-F5Del/Pur  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search



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eectrl:Copyeeeeee ITAS Node Data Entry For Thermal Analysis eeeeeeeESC:Quitet
□
□ SEQN NodeNo Temp-C ThrMass Dissip Comment
□ 541 3145 30 -.0002 0 PIN THROUGH 7.01 POLY LAYERS
□ 542 3142 30 -.0001 0 PIN THROUGH 7.01 COPPER LAYER
□ 543 3144 30 -.0001 0 PIN THROUGH 7.01 COPPER LAYER
□ 544 3146 30 -.0001 0 PIN THROUGH 7.01 COPPER LAYER
□ 545 3151 30 -.0017 .105 PIN THROUGH 7.02 POLY LAYERS
□ 546 3153 30 -.0017 0 PIN THROUGH 7.02 POLY LAYERS
□ 547 3155 30 -.0017 0 PIN THROUGH 7.02 POLY LAYERS
□ 548 3152 30 -.0001 0 PIN THROUGH 7.02 COPPER LAYERS
□ 549 3154 30 -.0001 0 PIN THROUGH 7.02 COPPER LAYERS
□ 550 3156 30 -.0001 0 PIN THROUGH 7.02 COPPER LAYERS
□ 551 3161 30 -.0020 .150 PIN THROUGH 7.03 POLY LAYERS
□ 552 3163 30 -.0020 0 PIN THROUGH 7.03 POLY LAYERS
□ 553 3165 30 -.0020 0 PIN THROUGH 7.03 POLY LAYERS
□ 554 3162 30 -.0001 0 PIN THROUGH 7.03 COPPER LAYERS
□ 555 3164 30 -.0001 0 PIN THROUGH 7.03 COPPER LAYERS
□ 556 3166 30 -.0001 0 PIN THROUGH 7.03 COPPER LAYERS
□ 557 3171 30 -.0004 0 PIN THROUGH 8.00 POLY LAYERS
□ 558 3173 30 -.0004 0 PIN THROUGH 8.00 POLY LAYERS

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aeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeey
CTRL-F1Import ITAS_NC UDC Allowed PgDn PgUp Home End
SHFT-F1Import Column Shift-F5Del/Pur
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

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eeCtrl:Copyeeeeee ITAS Node Data Entry For Thermal Analysis eeeeeeeESC:Quitet

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□
□ SEQN NodeNo Temp-C ThrMass Dissip Comment
□ 559 3175 30 -.0004 0 PIN THROUGH 8.00 POLY LAYERS
□ 560 3172 30 -.0001 0 PIN THROUGH 8.00 COPPER LAYERS
□ 561 3174 30 -.0001 0 PIN THROUGH 8.00 COPPER LAYERS
□ 562 3176 30 -.0001 0 PIN THROUGH 8.00 COPPER LAYERS
□ 563 2056 30 -.0001 0 PIN THROUGH 3.05 COPPER LAYER
□ 564 2124 30 -.0001 0 PIN THROUGH 3.12 COPPER LAYER
□ 565 2126 30 -.0001 0 PIN THROUGH 3.12 COPPER LAYER

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aeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeey
CTRL-F1Import ITAS_NC UDC Allowed PgDn PgUp Home End
SHFT-F1Import Column Shift-F5Del/Pur
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

# APPENDIX L. NODE TO NODE CONDUCTANCE CALCULATIONS

HOUSING TO HOUSING NODES						
From	To	Area	Length	k	Conductance	
901	905	0.3138	5.175	4.31	0.261348406	
901	906	1.88	5.2845	4.31	1.53331441	
901	911	0.3138	4.925	4.31	0.274614822	
901	912	1.6	5.0845	4.31	1.356278887	
902	903	0.3138	2.25	4.31	0.601101333	
902	906	0.47	4.7845	4.31	0.423388024	
902	907	0.3138	4.925	4.31	0.274614822	
902	912	0.45	4.5845	4.31	0.423055949	
903	904	0.3138	2.25	4.31	0.601101333	
903	906	0.45	4.5845	4.31	0.423055949	
903	912	0.45	4.5845	4.31	0.423055949	
904	905	0.3138	2.25	4.31	0.601101333	
904	906	0.45	4.5845	4.31	0.423055949	
904	912	0.45	4.5845	4.31	0.423055949	
905	906	0.45	4.5845	4.31	0.423055949	
905	912	0.45	4.5845	4.31	0.423055949	
907	906	4.925	1.6	4.31	13.26671875	
907	908	0.3138	4.925	4.31	0.274614822	
907	912	4.925	1.6	4.31	13.26671875	
908	906	0.45	4.5845	4.31	0.423055949	
908	909	0.3138	2.25	4.31	0.601101333	
908	912	0.45	4.5845	4.31	0.423055949	
909	906	0.45	4.5845	4.31	0.423055949	
909	910	0.3138	2.25	4.31	0.601101333	
909	912	0.45	4.5845	4.31	0.423055949	
910	906	0.45	4.5845	4.31	0.423055949	
910	911	0.3138	2.25	4.31	0.601101333	
910	912	0.45	4.5845	4.31	0.423055949	
911	906	0.45	4.5845	4.31	0.423055949	
911	912	0.45	4.5845	4.31	0.423055949	

PCB BOARD TO RAIL CONDUCTANCES							
		FROM	TO	AREA	LENGTH	k	Conductance
BOTTOM RAIL TO		921	901	0.0625	4.6	4.31	0.058559783
EPS HOUSING (+Y)		921	907	0.0625	4.6	4.31	0.058559783
		921	902	0.587	0.225	4.31	11.24431111
		921	903	0.587	0.225	4.31	11.24431111
		921	904	0.587	0.225	4.31	11.24431111
		921	905	0.587	0.225	4.31	11.24431111
		921	906	2.25	2.25	4.31	4.31
MIDDLE RAIL TO		922	901	0.09375	4.6	4.31	0.087839674
EPS HOUSING (+Y)		922	907	0.09375	4.6	4.31	0.087839674
		922	902	0.881	0.225	4.31	16.87604444
		922	903	0.881	0.225	4.31	16.87604444
		922	904	0.881	0.225	4.31	16.87604444
		922	905	0.881	0.225	4.31	16.87604444
TOP RAIL TO		923	901	0.04975	4.6	4.31	0.046613587
EPS HOUSING (+Y)		923	907	0.04975	4.6	4.31	0.046613587
		923	902	0.4279	0.225	4.31	8.196662222
		923	903	0.4677	0.225	4.31	8.959053333
		923	904	0.4677	0.225	4.31	8.959053333
		923	905	0.4279	0.225	4.31	8.196662222
		923	906	1.791	2.25	4.31	3.43076
BOTTOM RAIL TO		924	901	0.0625	4.6	4.31	0.058559783
EPS HOUSING (-Y)		924	907	0.0625	4.6	4.31	0.058559783
		924	908	0.5875	0.225	4.31	11.25388889
		924	909	0.5875	0.225	4.31	11.25388889
		924	910	0.587	0.225	4.31	11.24431111
		924	911	0.5875	0.225	4.31	11.25388889
		924	912	2.25	2.25	4.31	4.31
MIDDLE RAIL TO		925	901	0.09375	4.6	4.31	0.087839674
EPS HOUSING (-Y)		925	907	0.09375	4.6	4.31	0.087839674
		925	908	0.881	0.225	4.31	16.87604444
		925	909	0.881	0.225	4.31	16.87604444
		925	910	0.881	0.225	4.31	16.87604444
		925	911	0.881	0.225	4.31	16.87604444
TOP RAIL TO		926	901	0.04975	4.6	4.31	0.046613587
EPS HOUSING (-Y)		926	907	0.04975	4.6	4.31	0.046613587
		926	908	0.4279	0.225	4.31	8.196662222
		926	909	0.4677	0.225	4.31	8.959053333
		926	910	0.4677	0.225	4.31	8.959053333
		926	911	0.4279	0.225	4.31	8.196662222
		926	912	1.791	2.25	4.31	3.43076



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	628	922	0.3438	0.00067	0.1875	9.65	4.31	3.78	1.299564	4951.746	7.902816	1.115788
	629	922	0.3438	0.00067	0.1875	9.65	4.31	3.78	1.299564	4951.746	7.902816	1.115788
	630	922	0.6875	0.00067	0.1875	9.65	4.31	3.78	2.59875	9902.052	15.80333	2.231251
TOP PCB	101	926	0.3438	0.00967	0.0995	0.2	4.31	0.242	0.0832	7.110651	14.89224	0.081786
THERMAL	102	926	0.4688	0.00967	0.0995	0.2	4.31	0.242	0.11345	9.695967	20.30681	0.111522
LAYER	103	926	0.125	0.00967	0.0995	0.2	4.31	0.242	0.03025	2.585315	5.414573	0.029736
TO	104	926	0.5	0.00967	0.0995	0.2	4.31	0.242	0.121	10.34126	21.65829	0.118944
MIDDLE	105	926	0.125	0.00967	0.0995	0.2	4.31	0.242	0.03025	2.585315	5.414573	0.029736
RAIL	106	926	0.6875	0.00967	0.0995	0.2	4.31	0.242	0.166375	14.21923	29.78015	0.163548
	125	923	0.6875	0.00967	0.0995	0.2	4.31	0.242	0.166375	14.21923	29.78015	0.163548
	126	923	0.3438	0.00967	0.0995	0.2	4.31	0.242	0.0832	7.110651	14.89224	0.081786
	127	923	0.3438	0.00967	0.0995	0.2	4.31	0.242	0.0832	7.110651	14.89224	0.081786
	128	923	0.3438	0.00967	0.0995	0.2	4.31	0.242	0.0832	7.110651	14.89224	0.081786
	129	923	0.3438	0.00967	0.0995	0.2	4.31	0.242	0.0832	7.110651	14.89224	0.081786
	130	923	0.6875	0.00967	0.0995	0.2	4.31	0.242	0.166375	14.21923	29.78015	0.163548



TOP PCB THERMAL LAYER NODE TO NODE									
	FROM	TO	AREA	LENGTH	k	Conductance			
APPLIES TO LAYERS 4XX AND 2XX	601	602	0.003183	1.625	9.65	0.018902123			
	601	607	0.00184	2.625	9.65	0.00676419			
	602	603	0.003183	1.1875	9.65	0.025866063			
	602	608	0.02513	2.625	9.65	0.092382667			
	603	604	0.003138	1.25	9.65	0.02422536			
	603	609	0.0007	2.625	9.65	0.002573333			
	604	605	0.003183	1.25	9.65	0.02457276			
	604	610	0.00268	2.625	9.65	0.00985219			
	605	606	0.003138	2	9.65	0.018634892			
	605	611	0.0007	2.625	9.65	0.002573333			
	606	612	0.00369	2.625	9.65	0.013565143			
	607	608	0.00385	1.625	9.65	0.022863077			
	607	613	0.00184	1.84375	9.65	0.009630373			
	608	609	0.00385	1.875	9.65	0.019814667			
	608	613	0.0005	1.84375	9.65	0.002616949			
	608	614	0.00184	1.84375	9.65	0.009630373			
	608	615	0.00775	1.84375	9.65	0.040562712			
	609	610	0.00385	1.25	9.65	0.029722			
	609	615	0.0007	1.84375	9.65	0.003663729			
	610	611	0.00385	1.25	9.65	0.029722			
	610	615	0.001	1.84375	9.65	0.005233898			
	610	616	0.00168	1.84375	9.65	0.008792949			
	611	612	0.00385	1.625	9.65	0.022863077			
	611	616	0.00168	1.84375	9.65	0.008792949			
	611	617	0.0005	1.84375	9.65	0.002616949			
	612	617	0.00134	1.84375	9.65	0.007013424			
	612	618	0.00235	1.84375	9.65	0.012299661			
	613	614	0.00116	1.5625	9.65	0.00716416			
	613	619	0.00235	0.9375	9.65	0.024189333			
	614	615	0.00116	1.375	9.65	0.008141091			
	614	620	0.00184	0.9375	9.65	0.018939733			
	615	616	0.00116	1.375	9.65	0.008141091			

	615	621	0.00178	0.9375	9.65	0.018322133
	616	617	0.00116	1.375	9.65	0.008141091
	616	622	0.00184	0.9375	9.65	0.018939733
	617	618	0.00116	2	9.65	0.00716416
	617	623	0.00184	0.9375	9.65	0.018939733
	618	624	0.001	0.9375	9.65	0.010293333
	619	620	0.00142	1.5625	9.65	0.00876992
	619	625	0.00235	0.96875	9.65	0.023409032
	620	621	0.00142	1.375	9.65	0.009965818
	620	626	0.00184	0.96875	9.65	0.018328774
	621	622	0.00142	1.375	9.65	0.009965818
	621	627	0.00178	0.96875	9.65	0.017731097
	622	623	0.00142	0.96875	9.65	0.014145032
	622	628	0.00184	1.375	9.65	0.012913455
	623	624	0.00142	1.5625	9.65	0.00876992
	623	629	0.00184	0.96875	9.65	0.018328774
	624	630	0.001	0.96875	9.65	0.00996129
	625	626	0.00173	1.5625	9.65	0.01068448
	626	627	0.00173	1.375	9.65	0.012141455
	627	628	0.00173	1.375	9.65	0.012141455
	628	629	0.00173	1.375	9.65	0.012141455
	629	630	0.00173	1.5625	9.65	0.01068448

APPLIES TO LAYERS 3XX AND 1XX	FROM	TO	AREA	LENGTH	W	CONDUCTANCE
	501	502	0.04591	1.625	0.2	0.005650462
	501	507	0.02658	2.625	0.2	0.002025143
	502	503	0.04591	1.1874	0.2	0.007732862
	502	508	0.03624	2.625	0.2	0.002761143
	503	504	0.04591	1.25	0.2	0.0073456
	503	509	0.09665	2.625	0.2	0.00736381
	504	505	0.04591	1.25	0.2	0.0073456
	504	510	0.03866	2.625	0.2	0.002945524
	505	506	0.04591	1.625	0.2	0.005650462
	505	511	0.09665	2.625	0.2	0.00736381
	506	512	0.05316	2.625	0.2	0.004050286
	507	508	0.05557	1.625	0.2	0.006839385
	507	513	0.02658	1.184375	0.2	0.004488443
	508	509	0.05557	1.1875	0.2	0.009359158
	508	513	0.00725	1.184375	0.2	0.001224274
	508	514	0.02658	1.184375	0.2	0.004488443
	508	515	0.00242	1.184375	0.2	0.000408654
	509	510	0.05557	1.25	0.2	0.0088912
	509	515	0.09665	1.184375	0.2	0.016320844
	510	511	0.05557	1.25	0.2	0.0088912
	510	515	0.0145	1.184375	0.2	0.002448549
	510	516	0.024163	1.184375	0.2	0.004080296
	511	512	0.05557	2	0.2	0.006839385
	511	516	0.02416	1.184375	0.2	0.004079789
	511	517	0.007249	1.184375	0.2	0.001224106
	512	517	0.01933	1.184375	0.2	0.003264169
	512	518	0.033828	1.184375	0.2	0.00571238
	513	514	0.01576	1.562	0.2	0.002017926
	513	519	0.03383	0.9375	0.2	0.007217067
	514	515	0.015706	1.375	0.2	0.002284509
	514	520	0.02658	0.9375	0.2	0.0056704
	515	516	0.015706	1.375	0.2	0.002284509
	515	521	0.02658	0.9375	0.2	0.0056704

	516	517	0.015706	1.375	0.2	0.002284509
	516	522	0.02658	0.9375	0.2	0.0056704
	517	518	0.015706	1.5625	0.2	0.002010368
	517	523	0.02658	0.9375	0.2	0.0056704
	518	524	0.03383	0.9375	0.2	0.007217067
	519	520	0.02054	1.5625	0.2	0.00262912
	519	525	0.03383	0.96875	0.2	0.006984258
	520	521	0.02054	1.375	0.2	0.002987636
	520	526	0.02658	0.96875	0.2	0.005487484
	521	522	0.02054	1.375	0.2	0.002987636
	521	527	0.02658	0.96875	0.2	0.005487484
	522	523	0.02054	1.375	0.2	0.002987636
	522	528	0.02658	0.96875	0.2	0.005487484
	523	524	0.02054	1.5625	0.2	0.00262912
	523	529	0.02658	0.96875	0.2	0.005487484
	524	530	0.03383	0.96875	0.2	0.006984258
	525	526	0.01691	1.5625	0.2	0.00216448
	526	527	0.01691	1.375	0.2	0.002459636
	527	528	0.01691	1.375	0.2	0.002459636
	528	529	0.01691	1.375	0.2	0.002459636
	529	530	0.01691	1.5625	0.2	0.00216448



TOP PCB LAYER CONDUCTANCES													
APPLIES TO	FROM	TO	A1.2	L1	L2	k-Cu	k-poly	hc'	hc	K1	K2		K0
ALL TOP PCB LAYERS	601	501	3.2656	0.00067	0.00967	9.65	0.2	0.1933	0.63124	974.806	67.54085		0.624995
	602	502	4.4531	0.00067	0.00967	9.65	0.2	0.1933	0.860784	1329.284	92.10134		0.852267
	603	503	1.1875	0.00067	0.00967	9.65	0.2	0.1933	0.229544	354.4776	24.5605		0.227272
	604	504	4.75	0.00067	0.00967	9.65	0.2	0.1933	0.918175	1417.91	98.24199		0.90909
	605	505	4.75	0.00067	0.00967	9.65	0.2	0.1933	0.918175	1417.91	98.24199		0.90909
	606	506	6.531	0.00067	0.00967	9.65	0.2	0.1933	1.262442	1949.552	135.0776		1.249951
	607	507	3.953	0.00067	0.00967	9.65	0.2	0.1933	0.764115	1180	81.75801		0.756554
	608	508	5.391	0.00067	0.00967	9.65	0.2	0.1933	1.04208	1609.254	111.4995		1.031769
	609	509	1.4375	0.00067	0.00967	9.65	0.2	0.1933	0.277869	429.1045	29.73113		0.275119
	610	510	5.75	0.00067	0.00967	9.65	0.2	0.1933	1.111475	1716.418	118.9245		1.100477
	611	511	5.75	0.00067	0.00967	9.65	0.2	0.1933	1.111475	1716.418	118.9245		1.100477
	612	512	7.906	0.00067	0.00967	9.65	0.2	0.1933	1.52823	2360	163.516		1.513108
	613	513	1.421	0.00067	0.00967	9.65	0.2	0.1933	0.274679	424.1791	29.38987		0.271961
614	514	1.117	0.00067	0.00967	9.65	0.2	0.1933	0.215916	333.4328	23.10238		0.21378	
615	515	1.117	0.00067	0.00967	9.65	0.2	0.1933	0.215916	333.4328	23.10238		0.21378	
616	516	1.117	0.00067	0.00967	9.65	0.2	0.1933	0.215916	333.4328	23.10238		0.21378	
617	517	1.117	0.00067	0.00967	9.65	0.2	0.1933	0.215916	333.4328	23.10238		0.21378	
618	518	1.421	0.00067	0.00967	9.65	0.2	0.1933	0.274679	424.1791	29.38987		0.271961	
619	519	1.859	0.00067	0.00967	9.65	0.2	0.1933	0.359345	554.9254	38.44881		0.355789	
620	520	1.461	0.00067	0.00967	9.65	0.2	0.1933	0.282411	436.1194	30.21717		0.279617	
621	521	1.461	0.00067	0.00967	9.65	0.2	0.1933	0.282411	436.1194	30.21717		0.279617	
622	522	1.461	0.00067	0.00967	9.65	0.2	0.1933	0.282411	436.1194	30.21717		0.279617	
623	523	1.461	0.00067	0.00967	9.65	0.2	0.1933	0.282411	436.1194	30.21717		0.279617	
624	524	1.859	0.00067	0.00967	9.65	0.2	0.1933	0.359345	554.9254	38.44881		0.355789	
625	525	1.531	0.00067	0.00967	9.65	0.2	0.1933	0.295942	457.0149	31.66494		0.293014	
626	526	1.203	0.00067	0.00967	9.65	0.2	0.1933	0.23254	359.1045	24.88108		0.230239	
627	527	1.203	0.00067	0.00967	9.65	0.2	0.1933	0.23254	359.1045	24.88108		0.230239	
628	528	1.203	0.00067	0.00967	9.65	0.2	0.1933	0.23254	359.1045	24.88108		0.230239	
629	529	1.203	0.00067	0.00967	9.65	0.2	0.1933	0.23254	359.1045	24.88108		0.230239	
630	530	1.531	0.00067	0.00967	9.65	0.2	0.1933	0.295942	457.0149	31.66494		0.293014	





BOTTOM PCB POLY LAYER NODE TO NODE						
APPLIES TO LAYERS 13XX TO 11XX	FROM	TO	AREA	LENGTH	k	CONDUCTANCE
	1501	1502	0.058	1.281	0.2	0.009055425
	1501	1507	0.029	1.281	0.2	0.004527713
	1501	1514	0.0677	1.281	0.2	0.010569867
	1502	1503	0.058	1.344	0.2	0.008630952
	1502	1507	0.0302	2.25	0.2	0.002684444
	1503	1504	0.058	1.219	0.2	0.009515997
	1503	1508	0.0217	2.25	0.2	0.001928889
	1504	1505	0.058	0.906	0.2	0.012803532
	1504	1509	0.00846	2.25	0.2	0.000752
	1504	1510	0.00725	2.25	0.2	0.000644444
	1504	1511	0.00967	2.25	0.2	0.000859556
	1505	1506	0.058	1.5	0.2	0.007733333
	1505	1512	0.00967	2.25	0.2	0.000859556
	1506	1517	0.058	1.75	0.2	0.006628571
	1506	1513	0.0483	2.25	0.2	0.004293333
	1507	1508	0.029	1.344	0.2	0.004315476
	1507	1514	0.0302	2.5	0.2	0.002416
	1508	1509	0.029	1.438	0.2	0.004033338
	1508	1515	0.029	2.5	0.2	0.00232
	1509	1510	0.029	0.406	0.2	0.014285714
	1509	1515	0.00864	2.5	0.2	0.0006912
	1510	1511	0.029	0.438	0.2	0.013242009
	1510	1515	0.00725	2.5	0.2	0.00058
	1511	1512	0.029	0.5	0.2	0.0116
	1511	1515	0.00967	2.5	0.2	0.0007736
	1512	1513	0.029	1.5	0.2	0.003866667
	1512	1516	0.00967	2.5	0.2	0.0007736
	1513	1517	0.029	1.75	0.2	0.003314286
	1513	1516	0.0483	2.5	0.2	0.003864
	1514	1515	0.0677	2	0.2	0.00677
	1515	1516	0.0677	2.719	0.2	0.004979772
	1516	1517	0.0677	2	0.2	0.00677

BOTTOM PCB LAYER CONDUCTANCES													
LAYERS	FROM	TO	A1.2	L-Cu	L-poly	k-Cu	k-poly	hc'	hc	K1	K2	K0	
16XX TO 15XX	1601	1501	8	0.00067	0.00967	9.65	0.2	0.1933	1.5464	115223.9	165.4602	1.532061	
	1602	1502	4.688	0.00067	0.00967	9.65	0.2	0.1933	0.90619	67521.19	96.95967	0.897788	
	1603	1503	3.375	0.00067	0.00967	9.65	0.2	0.1933	0.652388	48610.07	69.80352	0.646338	
APPLIES TO ALL LAYER	1604	1504	3.938	0.00067	0.00967	9.65	0.2	0.1933	0.761215	56718.96	81.44778	0.754157	
	1605	1505	1.5	0.00067	0.00967	9.65	0.2	0.1933	0.28995	21604.48	31.02378	0.287261	
	1606	1506	7.5	0.00067	0.00967	9.65	0.2	0.1933	1.44975	108022.4	155.1189	1.436307	
TO LAYER CONDUCTANCES	1607	1507	2.344	0.00067	0.00967	9.65	0.2	0.1933	0.453095	33760.6	48.47983	0.448894	
	1608	1508	1.688	0.00067	0.00967	9.65	0.2	0.1933	0.32629	24312.24	34.9121	0.323265	
	1609	1509	0.6536	0.00067	0.00967	9.65	0.2	0.1933	0.126341	9413.791	13.5181	0.125169	
	1610	1510	0.562	0.00067	0.00967	9.65	0.2	0.1933	0.108635	8094.478	11.62358	0.107627	
	1611	1511	0.75	0.00067	0.00967	9.65	0.2	0.1933	0.144975	10802.24	15.51189	0.143631	
	1612	1512	0.75	0.00067	0.00967	9.65	0.2	0.1933	0.144975	10802.24	15.51189	0.143631	
	1613	1513	3.75	0.00067	0.00967	9.65	0.2	0.1933	0.724875	54011.19	77.55946	0.718153	
	1614	1514	5.471	0.00067	0.00967	9.65	0.2	0.1933	1.057544	78798.73	113.1541	1.047738	
	1615	1515	8.531	0.00067	0.00967	9.65	0.2	0.1933	1.649042	122871.9	176.4426	1.633751	
	1616	1516	10.5	0.00067	0.00967	9.65	0.2	0.1933	2.02965	151231.3	217.1665	2.01083	
	1617	1517	8	0.00067	0.00967	9.65	0.2	0.1933	1.5464	115223.9	165.4602	1.532061	



[illegible]





FROM	TO	AREA	k-Ni	L1	K1	R1	Ktot	k(Cu/poly)	hc'	hc	L2	K2	K0
3011	1101	0.00204	1.77	0.0165	0.218836	4.569624	14.00553	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3013	1301	0.00204	1.77	0.0165	0.218836	4.569624	14.00553	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3015	1501	0.00204	1.77	0.0165	0.218836	4.569624	14.00553	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3012	1201	0.00139	1.77	0.0165	0.149109	6.706499	9.542982	9.65	1.476	0.002052	0.025	0.53654	0.002043
3014	1401	0.00139	1.77	0.0165	0.149109	6.706499	9.542982	9.65	1.476	0.002052	0.025	0.53654	0.002043
3016	1601	0.00139	1.77	0.0165	0.149109	6.706499	9.542982	9.65	1.476	0.002052	0.025	0.53654	0.002043
3021	1102	0.00204	1.77	0.0165	0.218836	4.569624	7.440436	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3023	1302	0.00204	1.77	0.0165	0.218836	4.569624	7.440436	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3025	1502	0.00204	1.77	0.0165	0.218836	4.569624	7.440436	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3022	1202	0.00139	1.77	0.0165	0.149109	6.706499	5.069709	9.65	1.476	0.002052	0.025	0.53654	0.002043
3024	1402	0.00139	1.77	0.0165	0.149109	6.706499	5.069709	9.65	1.476	0.002052	0.025	0.53654	0.002043
3026	1602	0.00139	1.77	0.0165	0.149109	6.706499	5.069709	9.65	1.476	0.002052	0.025	0.53654	0.002043
3031	1103	0.00204	1.77	0.0165	0.218836	4.569624	7.002764	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3033	1303	0.00204	1.77	0.0165	0.218836	4.569624	7.002764	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3035	1503	0.00204	1.77	0.0165	0.218836	4.569624	7.002764	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3032	1203	0.00139	1.77	0.0165	0.149109	6.706499	4.771491	9.65	1.476	0.002052	0.025	0.53654	0.002043
3034	1403	0.00139	1.77	0.0165	0.149109	6.706499	4.771491	9.65	1.476	0.002052	0.025	0.53654	0.002043
3036	1603	0.00139	1.77	0.0165	0.149109	6.706499	4.771491	9.65	1.476	0.002052	0.025	0.53654	0.002043
3041	1104	0.00204	1.77	0.0165	0.218836	4.569624	7.002764	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3043	1304	0.00204	1.77	0.0165	0.218836	4.569624	7.002764	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3045	1504	0.00204	1.77	0.0165	0.218836	4.569624	7.002764	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3042	1204	0.00139	1.77	0.0165	0.149109	6.706499	4.771491	9.65	1.476	0.002052	0.025	0.53654	0.002043
3044	1404	0.00139	1.77	0.0165	0.149109	6.706499	4.771491	9.65	1.476	0.002052	0.025	0.53654	0.002043
3046	1604	0.00139	1.77	0.0165	0.149109	6.706499	4.771491	9.65	1.476	0.002052	0.025	0.53654	0.002043
3051	1105	0.00204	1.77	0.0165	0.218836	4.569624	6.127418	0.2	0.1773	0.000362	0.025	0.53654	0.002043
3053	1305	0.00204	1.77	0.0165	0.218836	4.569624	6.127418	0.2	0.1773	0.000362	0.025	0.53654	0.002043
3055	1505	0.00204	1.77	0.0165	0.218836	4.569624	6.127418	0.2	0.1773	0.000362	0.025	0.53654	0.002043
3052	1205	0.00139	1.77	0.0165	0.149109	6.706499	4.175055	9.65	1.476	0.002052	0.025	0.53654	0.002043
3054	1405	0.00139	1.77	0.0165	0.149109	6.706499	4.175055	9.65	1.476	0.002052	0.025	0.53654	0.002043
3056	1605	0.00139	1.77	0.0165	0.149109	6.706499	4.175055	9.65	1.476	0.002052	0.025	0.53654	0.002043
3061	1106	0.00204	1.77	0.0165	0.218836	4.569624	7.002764	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3063	1306	0.00204	1.77	0.0165	0.218836	4.569624	7.002764	0.2	0.1773	0.000362	0.025	0.01632	0.000354
3065	1506	0.00204	1.77	0.0165	0.218836	4.569624	7.002764	0.2	0.1773	0.000362	0.025	0.01632	0.000354





## APPENDIX M. ITAS CONDUCTANCE DATA

```

ēēē Ctrl:Copyēēēēēēēēēēēēē ITAS Conductor Data Entry ēēēēēēēēēēēēēēē ESC:Quit ē

```

SqNo	FACTOR	From	To	Cond.	Value	L/R	Description
1	1	1	901	1000		L	GEOMETRY TO HOUSING NODE
2	1	2	902	1000		L	GEOMETRY TO HOUSING NODE
3	1	3	903	1000		L	GEOMETRY TO HOUSING NODE
4	1	4	904	1000		L	GEOMETRY TO HOUSING NODE
5	1	5	905	1000		L	GEOMETRY TO HOUSING NODE
6	1	6	906	1000		L	GEOMETRY TO HOUSING NODE
7	1	7	907	1000		L	GEOMETRY TO HOUSING NODE
8	1	8	908	1000		L	GEOMETRY TO HOUSING NODE
9	1	9	909	1000		L	GEOMETRY TO HOUSING NODE
10	1	10	910	1000		L	GEOMETRY TO HOUSING NODE
11	1	11	911	1000		L	GEOMETRY TO HOUSING NODE
12	1	12	912	1000		L	GEOMETRY TO HOUSING NODE
13	1	13	613	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
14	1	14	614	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
15	1	15	615	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
16	1	16	616	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
17	1	17	617	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
18	1	18	618	1000		L	GEOMETRY TO PCB1 THERMAL LAYER

```

CTRL-F1Import ITAS_NC      ALT-F3AutoMLI      UDC Allowed      PgDn PgUp Home
SHFT-F1Import Column      Shift-F3AutoCHT    Shift-F5Del/Pur  End
      F1Save/Purge      F2Help F3AutoGen  F4Purge F5Delete  F7Mark/UnMark  F10Search.

```

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```

SqNo	FACTOR	From	To	Cond.	Value	L/R	Description
19	1	19	619	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
20	1	20	620	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
21	1	21	621	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
22	1	22	622	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
23	1	23	623	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
24	1	24	624	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
25	1	25	625	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
26	1	26	626	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
27	1	27	627	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
28	1	28	628	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
29	1	29	629	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
30	1	30	630	1000		L	GEOMETRY TO PCB1 THERMAL LAYER
31	1	31	601	1000		L	GEOMETRY TO TOP PCB THERMAL LAYER
32	1	32	602	1000		L	GEOMETRY TO TOP PCB THERMAL LAYER
33	1	33	603	1000		L	GEOMETRY TO TOP PCB THERMAL LAYER
34	1	34	604	1000		L	GEOMETRY TO TOP PCB THERMAL LAYER
35	1	35	605	1000		L	GEOMETRY TO TOP PCB THERMAL LAYER
36	1	36	606	1000		L	GEOMETRY TO TOP PCB THERMAL LAYER

```

CTRL-F1Import ITAS_NC      ALT-F3AutoMLI      UDC Allowed      PgDn PgUp Home
SHIFT-F1Import Column      Shift-F3AutoCHT      Shift-F5Del/Pur      End
      F1Save/Purge      F2Help F3AutoGen  F4Purge F5Delete  F7Mark/UnMark  F10Search

```

```

Ctrl:CopyXXXXXXXXXX ITAS Conductor Data Entry XXXXXXXXXXXXXXXXXXXX ESC:Quit f
□
□ SqNo FACTOR From To Cond. Value L/R Description
□ 19 1 19 619 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 20 1 20 620 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 21 1 21 621 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 22 1 22 622 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 23 1 23 623 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 24 1 24 624 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 25 1 25 625 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 26 1 26 626 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 27 1 27 627 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 28 1 28 628 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 29 1 29 629 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 30 1 30 630 1000 L GEOMETRY TO PCB1 THERMAL LAYER
□ 31 1 31 601 1000 L GEOMETRY TO TOP PCB THERMAL LAYER
□ 32 1 32 602 1000 L GEOMETRY TO TOP PCB THERMAL LAYER
□ 33 1 33 603 1000 L GEOMETRY TO TOP PCB THERMAL LAYER
□ 34 1 34 604 1000 L GEOMETRY TO TOP PCB THERMAL LAYER
□ 35 1 35 605 1000 L GEOMETRY TO TOP PCB THERMAL LAYER
□ 36 1 36 606 1000 L GEOMETRY TO TOP PCB THERMAL LAYER
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXY
CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHIFT-F1Import Column Shift-F3AutoGHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```





```

Ctrl:CopyITAS Conductor Data Entry ESC:Quit
SqNo FACTOR From To Cond. Value L/R Description
73 1 904 906 .42306 L HOUSING TO HOUSING NODES
74 1 904 912 .42306 L HOUSING TO HOUSING NODES
75 1 905 906 .42306 L HOUSING TO HOUSING NODES
76 1 905 912 .42306 L HOUSING TO HOUSING NODES
77 1 907 906 13.2667 L HOUSING TO HOUSING NODES
78 1 907 908 .27461 L HOUSING TO HOUSING NODES
79 1 907 912 13.2667 L HOUSING TO HOUSING NODES
80 1 908 906 .42306 L HOUSING TO HOUSING NODES
81 1 908 910 .60110 L HOUSING TO HOUSING NODES
82 1 908 912 .42306 L HOUSING TO HOUSING NODES
83 1 909 906 .42306 L HOUSING TO HOUSING NODES
84 1 909 910 .60110 L HOUSING TO HOUSING NODES
85 1 909 912 .42306 L HOUSING TO HOUSING NODES
86 1 910 906 .42306 L HOUSING TO HOUSING NODES
87 1 910 911 .60110 L HOUSING TO HOUSING NODES
88 1 910 912 .42306 L HOUSING TO HOUSING NODES
89 1 911 906 .42306 L HOUSING TO HOUSING NODES
90 1 911 912 .42306 L HOUSING TO HOUSING NODES

```

```

CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

```

Ctrl:CopyITAS Conductor Data Entry ESC:Quit
SqNo FACTOR From To Cond. Value L/R Description
91 1 921 901 .05856 L BOTTOM RAIL TO EPS HOUSING (+Y)
92 1 921 907 .05856 L BOTTOM RAIL TO EPS HOUSING (+Y)
93 1 921 902 11.2443 L BOTTOM RAIL TO EPS HOUSING (+Y)
94 1 921 903 11.2443 L BOTTOM RAIL TO EPS HOUSING (+Y)
95 1 921 904 11.2443 L BOTTOM RAIL TO EPS HOUSING (+Y)
96 1 921 905 11.2443 L BOTTOM RAIL TO EPS HOUSING (+Y)
97 1 921 906 4.31 L BOTTOM RAIL TO EPS HOUSING (+Y)
98 1 922 901 .08784 L MIDDLE RAIL TO EPS HOUSING (+Y)
99 1 922 907 .08784 L MIDDLE RAIL TO EPS HOUSING (+Y)
100 1 922 902 16.8760 L MIDDLE RAIL TO EPS HOUSING (+Y)
101 1 922 903 16.8760 L MIDDLE RAIL TO EPS HOUSING (+Y)
102 1 922 904 16.8760 L MIDDLE RAIL TO EPS HOUSING (+Y)
103 1 922 905 16.8760 L MIDDLE RAIL TO EPS HOUSING (+Y)
104 1 923 901 .04661 L TOP RAIL TO EPS HOUSING (+Y)
105 1 923 907 .04661 L TOP RAIL TO EPS HOUSING (+Y)
106 1 923 902 8.19666 L TOP RAIL TO EPS HOUSING (+Y)
107 1 923 903 8.95905 L TOP RAIL TO EPS HOUSING (+Y)
108 1 923 904 8.95905 L TOP RAIL TO EPS HOUSING (+Y)

```

```

CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

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CTRL-F1Import ITAS_NC      ALT-F3AutoMLI      UDC Allowed      PgDn PgUp Home
SHIFT-F1Import Column      Shift-F3AutoCHT      Shift-F5Del/Pur      End
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```



```

    Ctrl:Copy      ITAS Conductor Data Entry          ESC:Quit f
   SqNo FACTOR From To Cond. Value L/R Description
   199 1        610 615 .005234 L TOP PCB THRML LYR NODE-NODE
   200 1        610 616 .008793 L
   201 1        611 612 .022863 L
   202 1        611 616 .008793 L
   203 1        611 617 .002617 L
   204 1        612 617 .007013 L
   205 1        612 618 .01230 L
   206 1        613 614 .007164 L
   207 1        613 619 .024189 L
   208 1        614 615 .008141 L
   209 1        614 620 .018940 L
   210 1        615 616 .008141 L
   211 1        615 621 .01832 L
   212 1        616 617 .008141 L
   213 1        616 622 .018940 L
   214 1        617 618 .007164 L
   215 1        617 623 .018940 L
   216 1        618 624 .010293 L
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa~v
CTRL-FImport ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```





```

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit f
SqNo FACTOR From To Cond. Value L/R Description
307 1 410 416 .008793 L TOP PCB GRND LYR NODE-NODE
308 1 411 412 .022863 L
309 1 411 416 .008793 L
310 1 411 417 .002617 L
311 1 412 417 .007013 L
312 1 412 418 .01230 L
313 1 413 414 .007164 L
314 1 413 419 .024189 L
315 1 414 415 .008141 L
316 1 414 420 .018940 L
317 1 415 416 .008141 L
318 1 415 421 .018322 L
319 1 416 417 .008141 L
320 1 416 422 .018940 L
321 1 417 418 .007164 L
322 1 417 423 .018940 L
323 1 418 424 .010293 L
324 1 419 420 .008770 L
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa~v
CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```





```

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit f
SgNo FACTOR From To Cond. Value L/R Description
379 1 319 325 .006984 L TOP PCB MID POLY LYR NODE-NODE
380 1 320 321 .002988 L
381 1 320 326 .005487 L
382 1 321 322 .002988 L
383 1 321 327 .005487 L
384 1 322 323 .002988 L
385 1 322 328 .005487 L
386 1 323 324 .002629 L
387 1 323 329 .005487 L
388 1 324 330 .06984 L
389 1 325 326 .002164 L
390 1 326 327 .002460 L
391 1 327 328 .002460 L
392 1 328 329 .002460 L
393 1 329 330 .002164 L
394 1 201 202 .018902 L TOP PCB TOP Cu LYR NODE-NODE
395 1 201 207 .006764 L
396 1 202 203 .025866 L
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaay
CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

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    Ctrl:Copy##### ITAS Conductor Data Entry ##### ESC:Quit f
    □
    □ SqNo FACTOR From To Cond. Value L/R Description
    □ 469 1 110 116 .004080 L TOP PCB TOP POLY LYR NODE-NODE
    □ 470 1 111 112 .006839 L
    □ 471 1 111 116 .004080 L
    □ 472 1 111 117 .001224 L
    □ 473 1 112 117 .032642 L
    □ 474 1 112 118 .005712 L
    □ 475 1 113 114 .002018 L
    □ 476 1 113 119 .007217 L
    □ 477 1 114 115 .002285 L
    □ 478 1 114 120 .005670 L
    □ 479 1 115 116 .002285 L
    □ 480 1 115 621 .005670 L
    □ 481 1 116 117 .002845 L
    □ 482 1 116 122 .005670 L
    □ 483 1 117 118 .002010 L
    □ 484 1 117 123 .005670 L
    □ 485 1 118 124 .007217 L
    □ 486 1 119 120 .002629 L

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□
□ SqNo FACTOR From To Cond. Value L/R Description □
□ 487 1 119 125 .006984 L TOP PCB TOP POLY LYR NODE-NODE □
□ 488 1 120 121 .002988 L □
□ 489 1 120 126 .005487 L □
□ 490 1 121 122 .002988 L □
□ 491 1 121 127 .005487 L □
□ 492 1 122 123 .002988 L □
□ 493 1 122 128 .005487 L □
□ 494 1 123 124 .002629 L □
□ 495 1 123 129 .005487 L □
□ 496 1 124 130 .006984 L □
□ 497 1 125 126 .002164 L □
□ 498 1 126 127 .002460 L □
□ 499 1 127 128 .002460 L □
□ 500 1 128 129 .002460 L □
□ 501 1 129 130 .000164 L □
□ 502 1 601 501 .625 L TOP PCB LAYER 6XX TO 5XX □
□ 503 1 602 502 .85227 L TOP PCB LAYER 6XX TO 5XX □
□ 504 1 603 503 .22727 L TOP PCB LAYER 6XX TO 5XX □

```

[illegible]



[illegible]





```

Ctrl:Copy
SgNo FACTOR From To Cond. Value L/R Description
649 1 228 128 .23024 L TOP PCB LAYER 2XX T01XX
650 1 229 129 .23024 L TOP PCB LAYER 2XX T01XX
651 1 230 130 .29301 L TOP PCB LAYER 2XX T01XX
652 1 1601 1602 .0006276 L BOTTOM PCB THERMAL LYR NODE-NODE
653 1 1601 1607 .0003138 L
654 1 1601 1614 .0007322 L
655 1 1602 1603 .0005983 L
656 1 1602 1607 .0002613 L
657 1 1603 1604 .0006597 L
658 1 1603 1608 .0001342 L
659 1 1604 1605 .0008874 L
660 1 1604 1609 .0000524 L
661 1 1604 1610 .0000444 L
662 1 1604 1611 .0000560 L
663 1 1605 1606 .000536 L
664 1 1605 1612 .0000524 L
665 1 1606 1617 .0004594 L
666 1 1606 1613 .0002978 L

```

```

Ctrl:Copy
CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

```

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

```

```

SgNo FACTOR From To Cond. Value L/R Description
667 1 1607 1608 .0002992 L BOTTOM PCB THERMAL LYR NODE-NODE
668 1 1607 1614 .0001861 L
669 1 1608 1609 .0002780 L
670 1 1608 1615 .0001340 L
671 1 1609 1610 .0009901 L
672 1 1609 1615 .0000524 L
673 1 1610 1611 .0009178 L
674 1 1610 1615 .0000444 L
675 1 1611 1612 .000804 L
676 1 1611 1615 .0000560 L
677 1 1612 1613 .000268 L
678 1 1612 1616 .0000596 L
679 1 1613 1617 .0003829 L
680 1 1613 1616 .0003752 L
681 1 1614 1615 .000469 L
682 1 1615 1616 .0003450 L
683 1 1616 1617 .000469 L
684 1 1501 1502 .009055 L BOTTOM PCB BTM POLY LYR NODE-NODE

```

```

Ctrl:Copy
CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
685	1	1501	1507	.004528	L	BOTTOM PCB BTM POLY LYR NODE-NODE
686	1	1501	1514	.010570	L	
687	1	1502	1503	.008631	L	
688	1	1502	1507	.002684	L	
689	1	1503	1504	.009516	L	
690	1	1503	1508	.001929	L	
691	1	1504	1505	.01280	L	
692	1	1504	1509	.000752	L	
693	1	1504	1510	.000644	L	
694	1	1504	1511	.000860	L	
695	1	1505	1506	.007733	L	
696	1	1505	1512	.000860	L	
697	1	1506	1517	.006629	L	
698	1	1506	1513	.004293	L	
699	1	1507	1508	.004315	L	
700	1	1507	1514	.002416	L	
701	1	1508	1509	.004033	L	
702	1	1508	1515	.00232	L	

Ctrl-F1Import ITAS\_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home  
SHFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Conductor Data Entry ESC:Quit

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
703	1	1509	1510	.01429	L	BOTTOM PCB BTM POLY LYR NODE-NODE
704	1	1509	1515	.000691	L	
705	1	1510	1511	.01324	L	
706	1	1510	1515	.00058	L	
707	1	1511	1512	.0116	L	
708	1	1511	1515	.000774	L	
709	1	1512	1513	.003867	L	
710	1	1512	1516	.000774	L	
711	1	1513	1517	.003314	L	
712	1	1513	1516	.003864	L	
713	1	1514	1515	.00677	L	
714	1	1515	1516	.004980	L	
715	1	1516	1517	.00677	L	
716	1	1401	1402	.000628	L	BOTTOM PCB GRND LYR NODE-NODE
717	1	1401	1407	.000314	L	
718	1	1401	1414	.000732	L	
719	1	1402	1403	.000598	L	
720	1	1402	1407	.000261	L	

Ctrl-F1Import ITAS\_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home  
SHFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End  
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

Ctrl:CopyITAS Conductor Data Entry ESC:Quit
SqNo FACTOR From To Cond. Value L/R Description
721 1 1403 1404 .0006597 L BOTTOM PCB GRND LYR NODE-NODE
722 1 1403 1408 .0001342 L
723 1 1404 1405 .0008874 L
724 1 1404 1409 .0000524 L
725 1 1404 1410 .0000444 L
726 1 1404 1411 .0000596 L
727 1 1405 1406 .0005366 L
728 1 1405 1412 .0000524 L
729 1 1406 1417 .0004594 L
730 1 1406 1413 .0002978 L
731 1 1407 1408 .0002991 L
732 1 1407 1414 .0001861 L
733 1 1408 1409 .0002796 L
734 1 1408 1415 .0001340 L
735 1 1409 1410 .0009901 L
736 1 1409 1415 .0000524 L
737 1 1410 1411 .0009178 L
738 1 1410 1415 .0000444 L

```

```

CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

```

Ctrl:CopyITAS Conductor Data Entry ESC:Quit

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```

SqNo FACTOR From To Cond. Value L/R Description
739 1 1411 1412 .000804 L BOTTOM PCB GRND LYR NODE-NODE
740 1 1411 1415 .0000596 L
741 1 1412 1413 .000268 L
742 1 1412 1416 .0000596 L
743 1 1413 1417 .0003829 L
744 1 1413 1416 .0003752 L
745 1 1414 1415 .000469 L
746 1 1415 1416 .0003450 L
747 1 1416 1417 .000469 L
748 1 1301 1302 .009055 L
749 1 1301 1307 .004528 L BOTTOM PCB MID POLY LYR NODE-NODE
750 1 1301 1314 .01060 L
751 1 1302 1303 .00863 L
752 1 1302 1307 .002684 L
753 1 1303 1304 .009516 L
754 1 1303 1308 .001929 L
755 1 1304 1305 .01280 L
756 1 1304 1309 .000752 L

```

```

CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHIFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```





```

eee Ctrl:Copyeeeeeeeeeeee ITAS Conductor Data Entry eeeeeeeeeeeeeee ESC:Quit f
□
□ SqNo FACTOR From To Cond. Value L/R Description
□ 793 1 1206 1217 .0004594 L BOTTOM PCB TOP Cu LYR NODE-NODE
□ 794 1 1206 1213 .0002978 L
□ 795 1 1207 1208 .0002992 L
□ 796 1 1207 1214 .0001861 L
□ 797 1 1208 1209 .0002796 L
□ 798 1 1208 1215 .0001340 L
□ 799 1 1209 1210 .0009901 L
□ 800 1 1209 1215 .0000524 L
□ 801 1 1210 1211 .0009178 L
□ 802 1 1210 1215 .0000444 L
□ 803 1 1211 1212 .000804 L
□ 804 1 1211 1215 .0000596 L
□ 805 1 1212 1213 .000268 L
□ 806 1 1212 1216 .0000596 L
□ 807 1 1213 1217 .0003829 L
□ 808 1 1213 1216 .0003752 L
□ 809 1 1214 1215 .000469 L
□ 810 1 1215 1216 .0003450 L

```

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àeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeV
CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

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eee Ctrl:Copyeeeeeeeeeeee ITAS Conductor Data Entry eeeeeeeeeeeeeee ESC:Quit f

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```

□
□ SqNo FACTOR From To Cond. Value L/R Description
□ 811 1 1216 1217 .000469 L BOTTOM PCB TOP Cu LYR NODE-NODE
□ 812 1 1101 1102 .009055 L BOTTOM PCB TOP POLY LYR NODE-NODE
□ 813 1 1101 1107 .004528 L
□ 814 1 1101 1114 .010570 L
□ 815 1 1102 1103 .008631 L
□ 816 1 1102 1107 .002684 L
□ 817 1 1103 1104 .009516 L
□ 818 1 1103 1108 .001929 L
□ 819 1 1104 1105 .012804 L
□ 820 1 1104 1109 .000752 L
□ 821 1 1104 1110 .000644 L
□ 822 1 1104 1111 .0008596 L
□ 823 1 1105 1106 .007733 L
□ 824 1 1105 1112 .0008596 L
□ 825 1 1106 1117 .006629 L
□ 826 1 1106 1113 .004293 L
□ 827 1 1107 1108 .004315 L
□ 828 1 1107 1114 .002416 L

```

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àeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeV
CTRL-F1Import ITAS_NC ALT-F3AutoMLI UDC Allowed PgDn PgUp Home
SHFT-F1Import Column Shift-F3AutoCHT Shift-F5Del/Pur End
F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

```

ESC:Quit f
ITAS Conductor Data Entry
SqNo FACTOR From To Cond. Value L/R Description
829 1 1108 1109 .004033 L BOTTOM PCB TOP POLY LYR NODE-NODE
830 1 1108 1115 .00232 L
831 1 1109 1110 .01429 L
832 1 1109 1115 .000691 L
833 1 1110 1111 .013242 L
834 1 1110 1115 .00058 L
835 1 1111 1112 .0116 L
836 1 1111 1115 .000774 L
837 1 1112 1113 .003867 L
838 1 1112 1116 .000774 L
839 1 1113 1117 .003314 L
840 1 1113 1116 .003864 L
841 1 1114 1115 .00677 L
842 1 1115 1116 .004980 L
843 1 1116 1117 .00677 L
844 1 1601 1501 1.53206 L BOTTOM PCB LAYER 16XX TO 15XX
845 1 1602 1502 .89779 L BOTTOM PCB LAYER 16XX TO 15XX
846 1 1603 1503 .64634 L BOTTOM PCB LAYER 16XX TO 15XX

```

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
847	1	1604	1504	.75416	L	BOTTOM PCB LAYER 16XX TO 15XX
848	1	1605	1505	.28726	L	BOTTOM PCB LAYER 16XX TO 15XX
849	1	1606	1506	1.43631	L	BOTTOM PCB LAYER 16XX TO 15XX
850	1	1607	1507	.44889	L	BOTTOM PCB LAYER 16XX TO 15XX
851	1	1608	1508	.323276	L	BOTTOM PCB LAYER 16XX TO 15XX
852	1	1609	1509	.12517	L	BOTTOM PCB LAYER 16XX TO 15XX
853	1	1610	1510	.10763	L	BOTTOM PCB LAYER 16XX TO 15XX
854	1	1611	1511	.14363	L	BOTTOM PCB LAYER 16XX TO 15XX
855	1	1612	1512	.14363	L	BOTTOM PCB LAYER 16XX TO 15XX
856	1	1613	1513	.71815	L	BOTTOM PCB LAYER 16XX TO 15XX
857	1	1614	1514	1.04774	L	BOTTOM PCB LAYER 16XX TO 15XX
858	1	1615	1515	1.63375	L	BOTTOM PCB LAYER 16XX TO 15XX
859	1	1616	1516	2.0108	L	BOTTOM PCB LAYER 16XX TO 15XX
860	1	1617	1517	1.53206	L	BOTTOM PCB LAYER 16XX TO 15XX
861	1	1501	1401	1.53206	L	BOTTOM PCB LAYER 15XX TO 14XX
862	1	1502	1402	.89779	L	BOTTOM PCB LAYER 15XX TO 14XX
863	1	1503	1403	.64634	L	BOTTOM PCB LAYER 15XX TO 14XX
864	1	1504	1404	.75416	L	BOTTOM PCB LAYER 15XX TO 14XX

CTRL:Copy

ESC:Quit

ITAS Conductor Data Entry

ESC:Quit

CTRL-F1Import ITAS\_NC

ALT-F3AutoMLI

UDC Allowed

PgDn PgUp Home

SHIFT-F1Import Column

Shift-F3AutoCHT

Shift-F5Del/Pur

End

F1Save/Purge

F2Help F3AutoGen

F4Purge F5Delete

F7Mark/UnMark F10Search

```

aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaay
CTRL-F1Import ITAS_NC      ALT-F3AutoMLI    UDC Allowed          PgDn PgUp Home
SHIFT-F1Import Column     Shift-F3AutoCHT   Shift-F5Del/Pur      End
      F1Save/Purge        F2Help F3AutoGen  F4Purge F5Delete    F7Mark/UnMark F10Search

```



```

CTRL-F1Import ITAS_NC      ALT-F3AutoMLI    UDC Allowed          PgDn PgUp Home
SHFT-F1Import Column      Shift-F3AutoCHT   Shift-F5Del/Pur      End
F1Save/Purge              F2Help F3AutoGen  F4Purge F5Delete     F7Mark/UnMark F10Search

```

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
919	1	1208	1108	.32327	L	BOTTOM PCB LAYER 12XX TO11XX
920	1	1209	1109	.12517	L	BOTTOM PCB LAYER 12XX TO11XX
921	1	1210	1110	.10763	L	BOTTOM PCB LAYER 12XX TO11XX
922	1	1211	1111	.14363	L	BOTTOM PCB LAYER 12XX TO11XX
923	1	1212	1112	.14363	L	BOTTOM PCB LAYER 12XX TO11XX
924	1	1213	1113	.71815	L	BOTTOM PCB LAYER 12XX TO11XX
925	1	1214	1114	1.04774	L	BOTTOM PCB LAYER 12XX TO11XX
926	1	1215	1115	1.63375	L	BOTTOM PCB LAYER 12XX TO11XX
927	1	1216	1116	2.01083	L	BOTTOM PCB LAYER 12XX TO11XX
928	1	1217	1117	1.53206	L	BOTTOM PCB LAYER 12XX TO11XX
929	1	2011	101	.000296	L	EQUIV PIN CONDUCTANCE 3.01
930	1	2012	201	.000197	L	EQUIV PIN CONDUCTANCE 3.01
931	1	2013	301	.000296	L	EQUIV PIN CONDUCTANCE 3.01
932	1	2014	401	.000176	L	EQUIV PIN CONDUCTANCE 3.01
933	1	2015	501	.000296	L	EQUIV PIN CONDUCTANCE 3.01
934	1	2016	601	.000197	L	EQUIV PIN CONDUCTANCE 3.01
935	1	2021	102	.000296	L	EQUIV CONDUCTANCE FOR 3.02
936	1	2022	202	.000197	L	EQUIV CONDUCTANCE FOR 3.02

```

CTRL-F1Import ITAS_NC      ALT-F3AutoMLI      UDC Allowed      PgDn PgUp Home
SHIFT-F1Import Column      Shift-F3AutoCHT      Shift-F5Del/Pur      End
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search.

```



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ēēē Ctrl:Copyēēēēēēēēēēēēēē ITAS Conductor Data Entry ēēēēēēēēēēēēēēēē ESC:Quit ē

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SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1081	1	2263	326	.000296	L	EQUIV PIN COND FOR 2.14
1082	1	2264	426	.000197	L	EQUIV PIN COND FOR 2.14
1083	1	2265	526	.000296	L	EQUIV PIN COND FOR 2.14
1084	1	2266	626	.000197	L	EQUIV PIN COND FOR 2.14
1085	1	2271	127	.000296	L	EQUIV PIN COND FOR 2.15
1086	1	2272	227	.000197	L	EQUIV PIN COND FOR 2.15
1087	1	2273	327	.000296	L	EQUIV PIN COND FOR 2.15
1088	1	2274	427	.000197	L	EQUIV PIN COND FOR 2.15
1089	1	2275	527	.000296	L	EQUIV PIN COND FOR 2.15
1090	1	2276	627	.000197	L	EQUIV PIN COND FOR 2.15
1091	1	2281	128	.000296	L	EQUIV PIN COND FOR 2.16
1092	1	2282	228	.000197	L	EQUIV PIN COND FOR 2.16
1093	1	2283	328	.000296	L	EQUIV PIN COND FOR 2.16
1094	1	2284	428	.000197	L	EQUIV PIN COND FOR 2.16
1095	1	2285	528	.000296	L	EQUIV PIN COND FOR 2.16
1096	1	2286	628	.000197	L	EQUIV PIN COND FOR 2.16
1097	1	2291	129	.000296	L	EQUIV PIN COND FOR 2.17
1098	1	2292	229	.000197	L	EQUIV PIN COND FOR 2.17

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SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1099	1	2293	329	.000296	L	EQUIV PIN COND FOR 2.17
1100	1	2294	429	.000197	L	EQUIV PIN COND FOR 2.17
1101	1	2295	529	.000296	L	EQUIV PIN COND FOR 2.17
1102	1	2296	629	.000197	L	EQUIV PIN COND FOR 2.17
1103	1	2301	130	.000296	L	EQUIV PIN COND FOR 2.18
1104	1	2302	230	.000197	L	EQUIV PIN COND FOR 2.18
1105	1	2303	330	.000296	L	EQUIV PIN COND FOR 2.18
1106	1	2304	430	.000197	L	EQUIV PIN COND FOR 2.18
1107	1	2305	530	.000296	L	EQUIV PIN COND FOR 2.18
1108	1	2306	630	.000197	L	EQUIV PIN COND FOR 2.18
1109	1	3011	1101	.000296	L	EQUIV PIN COND FOR 4.00
1110	1	3012	1201	.000197	L	EQUIV PIN COND FOR 4.00
1111	1	3013	1301	.000296	L	EQUIV PIN COND FOR 4.00
1112	1	3014	1401	.000197	L	EQUIV PIN COND FOR 4.00
1113	1	3015	1501	.000296	L	EQUIV PIN COND FOR 4.00
1114	1	3016	1601	.000197	L	EQUIV PIN COND FOR 4.00
1115	1	3021	1102	.000296	L	EQUIV PIN COND FOR 5.01
1116	1	3022	1202	.000197	L	EQUIV PIN COND FOR 5.01

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===== ITAS Conductor Data Entry ===== ESC:Quit f
|
| SqNo  FACTOR  From      To      Cond. Value  L/R  Description
|
| 1171  1       3143     1314    .000197      L   EQUIV PIN COND FOR 7.01
|
| 1172  1       3144     1414    .000296      L   EQUIV PIN COND FOR 7.01
|
| 1173  1       3145     1514    .000197      L   EQUIV PIN COND FOR 7.01
|
| 1174  1       3146     1614    .000296      L   EQUIV PIN COND FOR 7.01
|
| 1175  1       3151     1115    .000197      L   EQUIV PIN COND FOR 7.02
|
| 1176  1       3152     1215    .000296      L   EQUIV PIN COND FOR 7.02
|
| 1177  1       3153     1315    .000197      L   EQUIV PIN COND FOR 7.02
|
| 1178  1       3154     1415    .000296      L   EQUIV PIN COND FOR 7.02
|
| 1179  1       3155     1515    .000197      L   EQUIV PIN COND FOR 7.02
|
| 1180  1       3156     1615    .000296      L   EQUIV PIN COND FOR 7.02
|
| 1181  1       3161     1116    .000197      L   EQUIV PIN COND FOR 7.03
|
| 1182  1       3162     1216    .000296      L   EQUIV PIN COND FOR 7.03
|
| 1183  1       3163     1316    .000197      L   EQUIV PIN COND FOR 7.03
|
| 1184  1       3164     1416    .000296      L   EQUIV PIN COND FOR 7.03
|
| 1185  1       3165     1516    .000197      L   EQUIV PIN COND FOR 7.03
|
| 1186  1       3166     1616    .000296      L   EQUIV PIN COND FOR 7.03
|
| 1187  1       3171     1117    .000197      L   EQUIV PIN COND FOR 8.00
|
| 1188  1       3172     1217    .000296      L   EQUIV PIN COND FOR 8.00
|
|=====
|
| CTRL-F1Import ITAS_NC      ALT-F3AutoMLI      UDC Allowed      PgDn PgUp Home
|
| SHFT-F1Import Column      Shift-F3AutoCHT      Shift-F5Del/Pur      End
|
|      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```



SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1189	1	3173	1317	.000296	L	EQUIV PIN COND FOR 8.00
1190	1	3174	1417	.000197	L	EQUIV PIN COND FOR 8.00
1191	1	3175	1517	.000296	L	EQUIV PIN COND FOR 8.00
1192	1	3176	1617	.000197	L	EQUIV PIN COND FOR 8.00
1193	1	2011	2012	.1465	L	PIN COND
1194	1	2012	2013	.1465	L	PIN COND
1195	1	2013	2014	.1465	L	PIN COND
1196	1	2014	2015	.1465	L	PIN COND
1197	1	2015	2016	.1465	L	PIN COND
1198	1	2021	2022	.1465	L	PIN COND
1199	1	2022	2023	.1465	L	PIN COND
1200	1	2023	2024	.1465	L	PIN COND
1201	1	2024	2025	.1465	L	PIN COND
1202	1	2025	2026	.1465	L	PIN COND
1203	1	2031	2032	.1465	L	PIN COND
1204	1	2032	2033	.1465	L	PIN COND
1205	1	2033	2034	.1465	L	PIN COND
1206	1	2034	2035	.1465	L	PIN COND

[illegible]

[illegible][illegible]







```

CTRL-F1Import ITAS_NC      ALT-F3AutoMLI      UDC Allowed      PgDn PgUp Home
SHIFT-F1Import Column     Shift-F3AutoCHT     Shift-F5Del/Pur  End
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

SqNo	FACTOR	From	To	Cond.	Value	L/R	Description
1351	1	3024	3025	.1465		L	PIN COND
1352	1	3025	3026	.1465		L	PIN COND
1353	1	3031	3032	.1465		L	PIN COND
1354	1	3032	3033	.1465		L	PIN COND
1355	1	3033	3034	.1465		L	PIN COND
1356	1	3034	3035	.1465		L	PIN COND
1357	1	3035	3036	.1465		L	PIN COND
1358	1	3041	3042	.1465		L	PIN COND
1359	1	3042	3043	.1465		L	PIN COND
1360	1	3043	3044	.1465		L	PIN COND
1361	1	3044	3045	.1465		L	PIN COND
1362	1	3045	3046	.1465		L	PIN COND
1363	1	3051	3052	.1465		L	PIN COND
1364	1	3052	3053	.1465		L	PIN COND
1365	1	3053	3054	.1465		L	PIN COND
1366	1	3054	3055	.1465		L	PIN COND
1367	1	3055	3056	.1465		L	PIN COND
1368	1	3061	3062	.1465		L	PIN COND

```

CTRL-F1Import ITAS_NC      ALT-F3AutoMLI      UDC Allowed      PgDn PgUp Home
SHIFT-F1Import Column      Shift-F3AutoCHT      Shift-F5Del/Pur      End
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

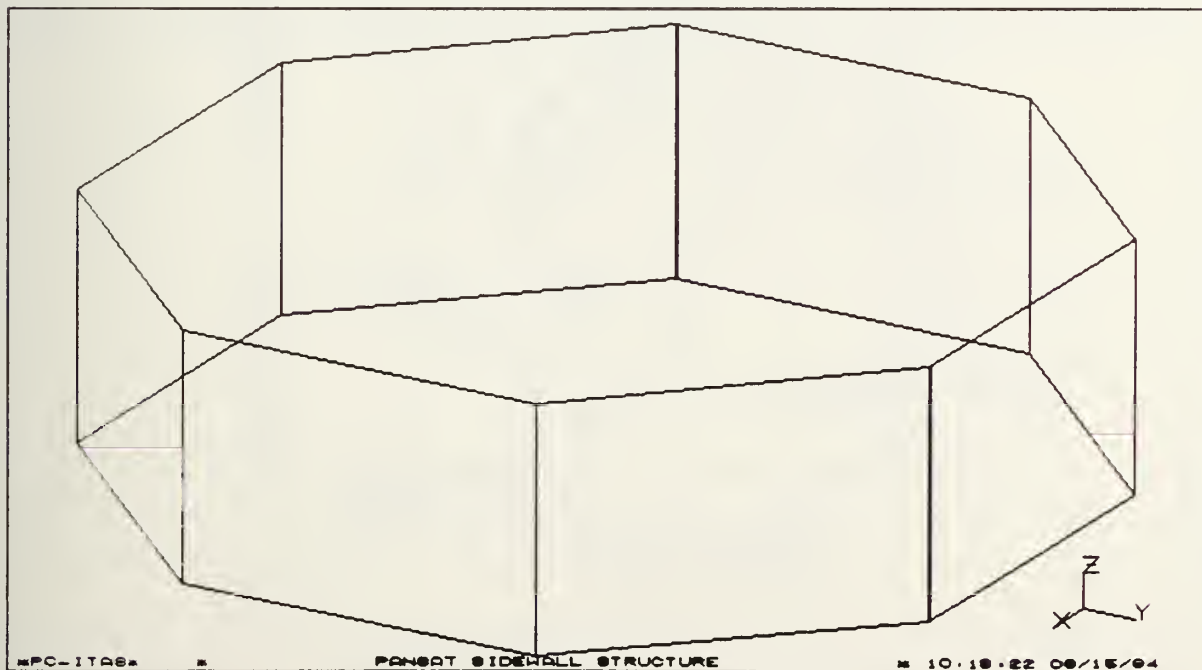
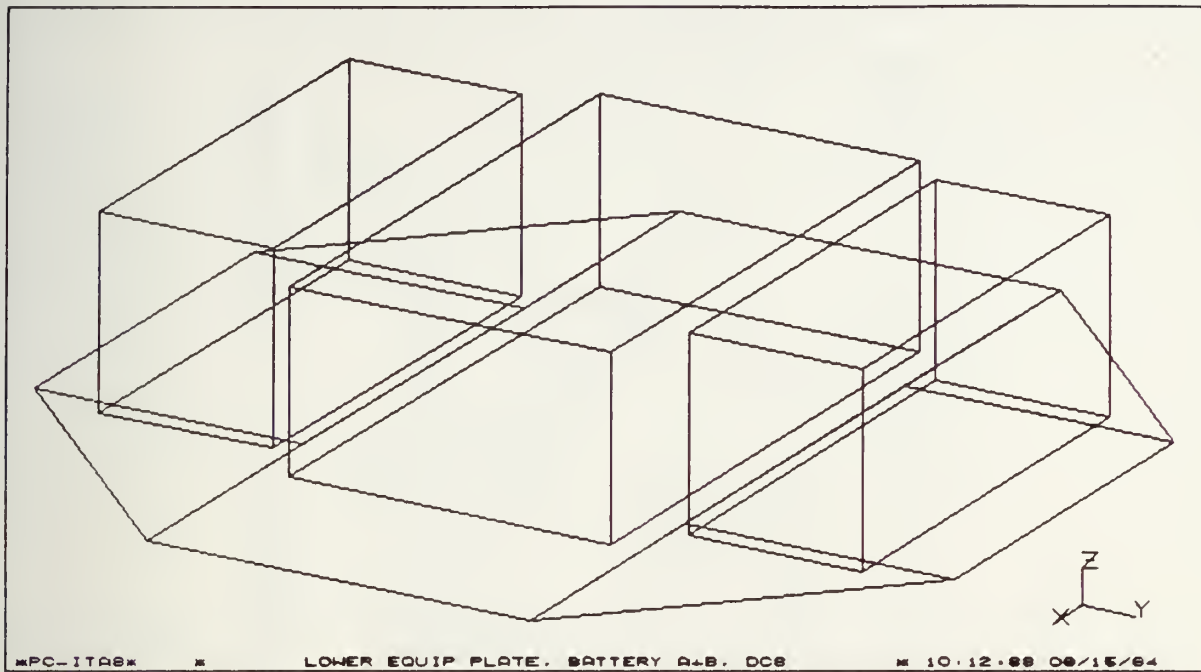


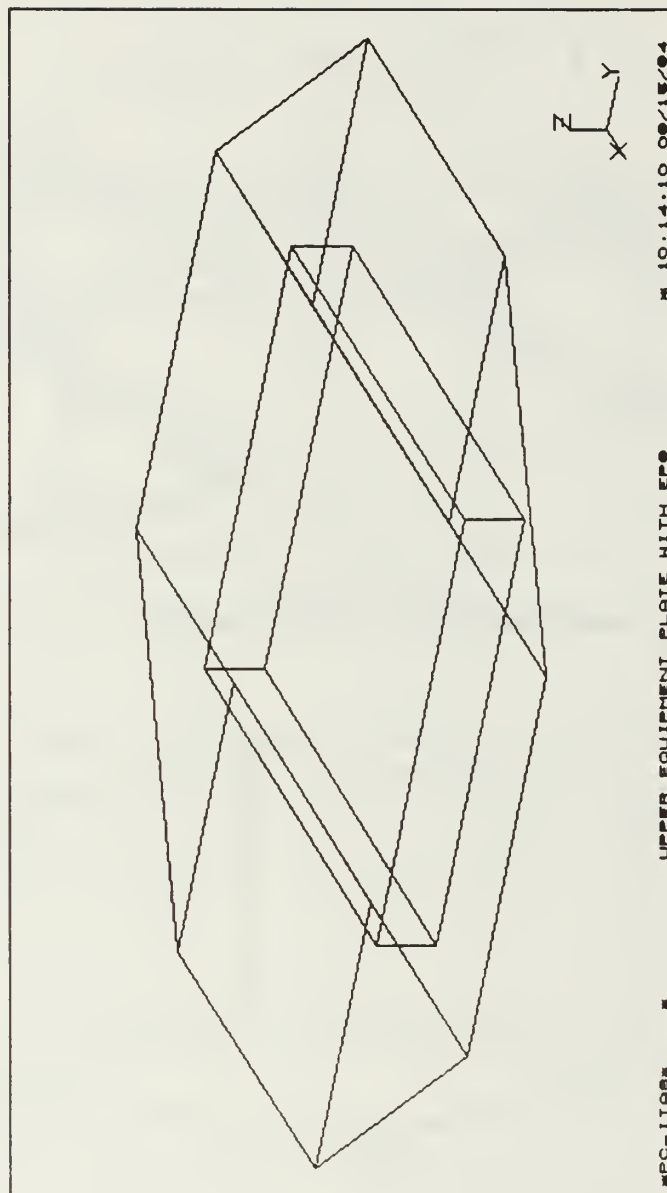




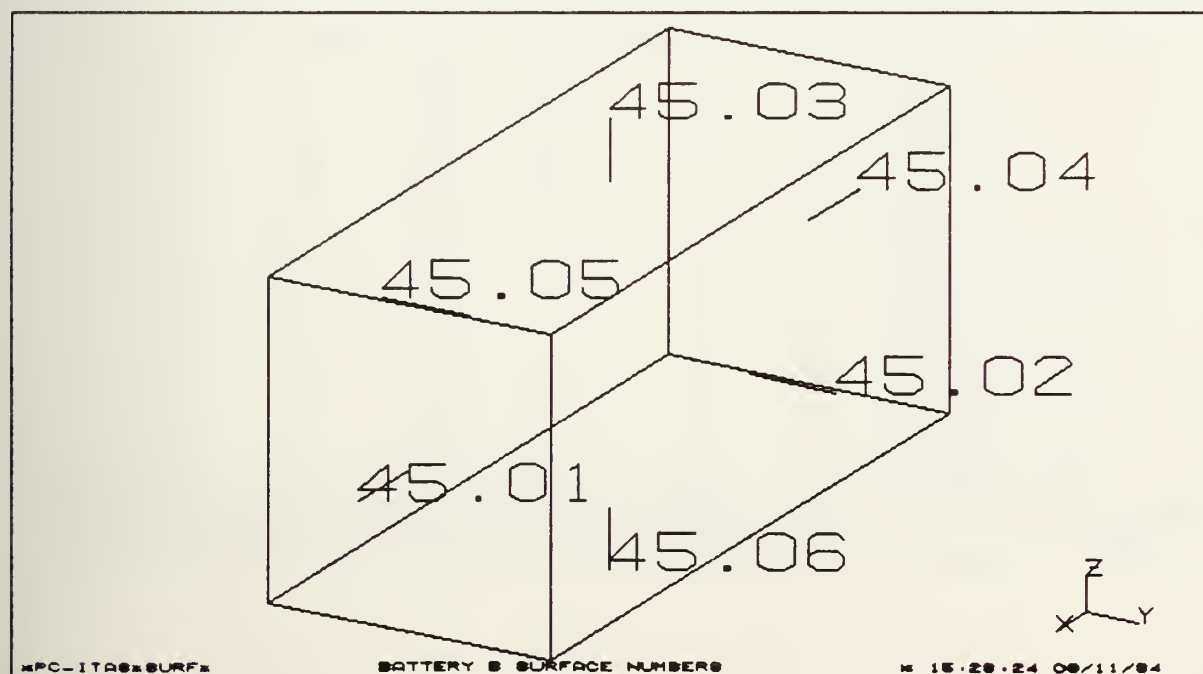
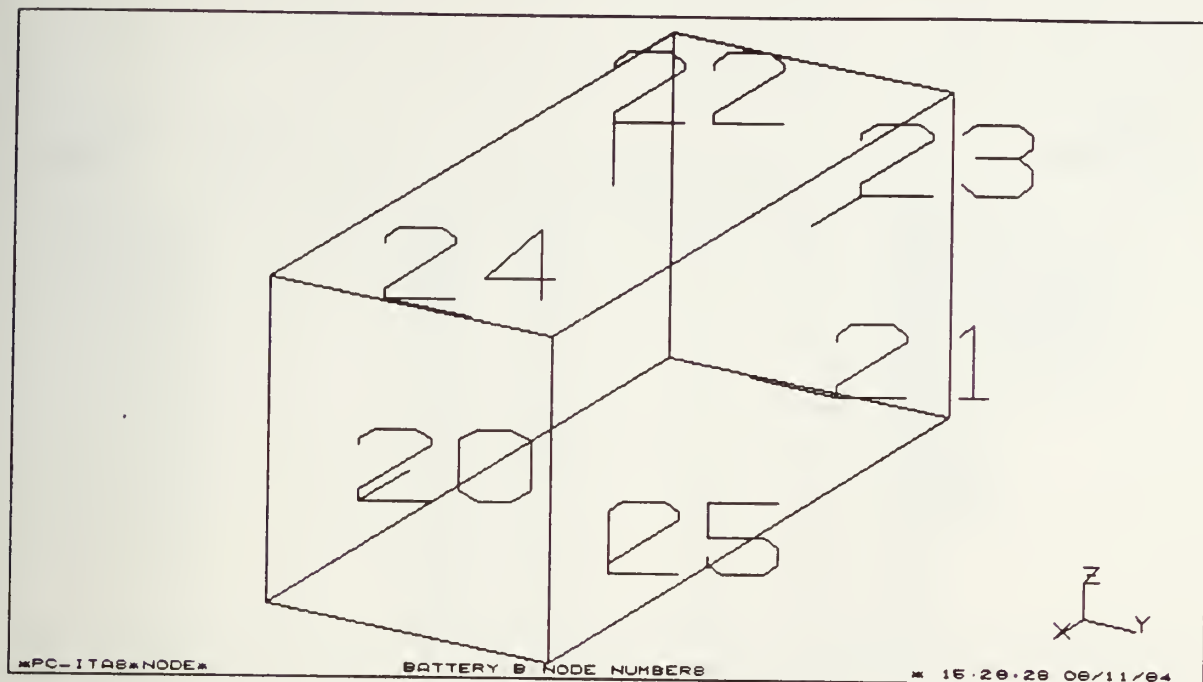


## APPENDIX N. ITAS BATTERY GEOMETRY MODEL





# APPENDIX O. BATTERY B SURFACE AND NODE NUMBERS









PgDn PgUp Home End F2Help  
 Ctrl : Copy (See F2) ITAS Property Data Entry

Seq	Surface No	NodeNo	Alpha	Emiss	T/Mass	Dissip	MID	Comments
29	65.00	29	0.400	0.790	1.	0.	144	UPPER EQUIPMENT PL
30	70.00	30	0.400	0.790	1.	0.	144	UPPER EQUIPMENT PL
31	75.00	31	0.400	0.790	1.	0.	144	UPPER EQUIPMENT PL
32	80.00	32	0.400	0.790	1.	0.	144	UPPER EQUIPMENT PL
33	82.00	33	0.400	0.790	1.	0.	144	STRUCTURE FRONT MI
34	84.00	34	0.400	0.790	1.	0.	144	STRUCTURE BACK MID
35	86.00	35	0.400	0.790	1.	0.	144	STRUCTURE RIGHT
36	88.00	36	0.400	0.790	1.	0.	144	STRUCTURE LEFT
37	92.00	37	0.400	0.790	1.	0.	144	RIGHT FRONT SLANT ;
38	94.00	38	0.400	0.790	1.	0.	144	RIGHT FRONT SLANT
39	96.00	39	0.400	0.790	1.	0.	144	BACK RIGHT SLANT
40	98.00	40	0.400	0.790	1.	0.	144	RIGHT BACK SLANT
41	99.01	41	0.400	0.790	1.	0.	144	EPS
42	99.02	42	0.400	0.790	1.	0.	144	EPS
43	99.03	43	0.400	0.790	1.	0.	144	EPS
44	99.04	44	0.400	0.790	1.	0.	144	EPS
45	99.05	45	0.400	0.790	1.	0.	144	EPS
46	99.06	46	0.400	0.790	1.	0.	144	EPS

S-F1Load/Save All S-F4Auto TM JDC Allowed ESCQuit  
 F1Load/Save Page F3PropLib F4AutoGen F5ImportPropFmt F6NewPropFile F10Search

# APPENDIX Q. PANSAT TRANSIENT STRUCTURAL ANALYSIS

Page No. 14

PANSAT - TRANSIENT - SUNLIGHT ZONE - INTERNAL HEAT DISSIPATION - PASS

temperatures, degC

1	32.40	2	33.67	3	35.07	4	32.09	5	33.59	6
7	32.47	8	33.54	9	34.69	10	39.58	11	40.61	12
3	39.76	14	41.05	15	41.37	16	37.92	17	38.77	18
9	39.37	20	38.62	21	37.18	22	40.80	23	39.98	24
5	39.06	26	38.54	27	37.08	28	32.28	29	30.99	30
1	32.08	32	30.41	33	30.00	34	31.71	35	30.53	36
7	30.37	38	30.57	39	31.03	40	30.01	41	30.40	42
3	30.86	44	31.25	45	31.81	46	32.11	47	32.55	48
9	33.21	50	33.87	51	34.13	52	33.26	53	33.70	54
5	33.03	56	32.75	57	31.78	58	34.11	59	33.68	60
1	34.11	62	33.80	63	32.85	64	28.40	65	27.87	66
7	28.78	68	27.91	69	28.55	70	29.55	71	28.89	72
3	27.73	74	29.43	75	33.79	76	29.45	77	32.27	78
9	31.11	80	33.04	81	35.23	82	40.46	83	40.30	84
5	41.20	86	40.80	87	41.71	88	37.21	89	35.10	90
1	38.88	92	37.05	93	35.60	94	38.35	95	36.90	96
7	30.16	98	29.48	99	30.39	100	29.48	101	31.61	102
3	26.29	104	24.59	105	24.93	106	26.60	107	25.48	108
9	28.50	110	27.98	111	28.44	112	26.73	113	26.73	114
5	28.95	116	29.86	117	30.52	118	26.24	119	25.88	120
1	27.85	122	27.19	123	26.76	124	29.65	125	29.14	126
7	25.70	128	25.89	129	25.45	130	25.64	131	26.63	132
3	29.72	134	30.52	135	32.04	136	28.14	137	28.85	138
9	28.05	140	28.30	141	32.10	142	35.42	143	36.06	144
5	37.12	146	41.06	147	41.32	148	34.91	149	33.95	150
1	34.88	152	32.97	153	31.51	154	34.69	155	31.77	156
7	29.53	158	28.94	159	29.44	160	28.94	161	30.75	162
3	30.26	164	30.91	165	31.62	166	29.16	167	29.75	168
9	29.46	170	29.18	171	31.59	172	32.18	173	32.52	174
5	33.63	176	36.91	177	37.05	178	33.01	179	32.11	180
1	33.09	182	31.86	183	30.65	184	33.02	185	31.00	186
7	28.43	188	28.02	189	28.73	190	28.23	191	30.26	192
3	25.04	194	25.51	195	28.20	196	25.32	197	26.39	198
9	25.99	200	27.55	201	31.35	202	29.36	203	27.91	204
5	28.22	206	27.24	207	28.56	208	27.73	209	27.67	210
1	33.97	212	34.66	213	34.63	214	33.51	215	32.24	216
7	31.45	218	31.15	219	33.70	220	34.39	221	34.43	222
3	33.33	224	33.48	225	33.44	226	33.39	227	32.78	228
9	30.58	230	30.52	231	28.77	232	28.61			
1	-272.80									

PANSAT - TRANSIENT - SHADOW ZONE - INTERNAL HEAT DISSIPATION - PA										Page
Temperatures, degC										PA
1	29.93	2	30.88	3	31.83	4	29.32	5	30.44	
7	30.08	8	30.85	9	31.66	10	33.00	11	33.64	
13	33.67	14	34.77	15	35.60	16	32.55	17	33.56	
19	33.64	20	33.04	21	31.97	22	34.48	23	33.54	
25	33.96	26	33.09	27	31.99	28	29.65	29	28.59	
31	29.66	32	28.44	33	28.27	34	29.57	35	28.79	
37	30.28	38	30.75	39	31.22	40	29.99	41	30.63	
43	30.77	44	31.38	45	31.91	46	32.44	47	32.83	
49	33.37	50	34.00	51	34.25	52	33.25	53	33.66	
55	33.23	56	32.94	57	31.97	58	34.26	59	33.84	
61	34.21	62	33.93	63	32.98	64	28.56	65	27.97	
67	28.95	68	28.07	69	28.38	70	29.67	71	28.99	
73	24.95	74	26.06	75	28.75	76	26.75	77	29.08	
79	28.75	80	30.26	81	31.09	82	29.42	83	29.52	
85	30.26	86	30.81	87	31.24	88	30.37	89	29.63	
91	31.86	92	31.57	93	30.88	94	32.42	95	32.12	
97	25.67	98	25.50	99	25.41	100	25.33	101	26.88	1
103	25.04	104	24.21	105	24.73	106	25.75	107	25.58	1
109	27.92	110	28.13	111	28.74	112	26.58	113	26.76	1
115	29.25	116	30.62	117	30.90	118	25.99	119	25.53	1
121	27.98	122	27.30	123	26.85	124	29.88	125	29.35	1
127	24.68	128	24.63	129	25.13	130	25.13	131	26.53	1
133	28.85	134	29.98	135	30.14	136	27.17	137	27.61	1
139	27.11	140	26.83	141	27.67	142	30.15	143	30.95	1
145	29.18	146	27.85	147	27.92	148	31.26	149	30.80	1
151	29.86	152	29.29	153	28.08	154	28.63	155	28.18	1
157	27.54	158	27.46	159	26.82	160	26.90	161	26.93	1
163	30.13	164	31.00	165	31.55	166	28.82	167	29.84	1
169	28.68	170	29.32	171	31.50	172	31.67	173	32.01	1
175	32.24	176	36.36	177	36.47	178	32.95	179	32.13	1
181	32.83	182	31.96	183	30.78	184	32.92	185	31.11	1
187	28.45	188	27.85	189	28.67	190	27.96	191	30.00	1
193	23.23	194	22.92	195	24.73	196	22.97	197	23.03	1
199	23.42	200	23.94	201	26.55	202	29.35	203	27.73	2
205	28.20	206	26.93	207	27.28	208	27.49	209	27.03	2
211	32.31	212	32.69	213	32.56	214	32.18	215	31.74	2
217	31.56	218	31.32	219	32.66	220	33.00	221	32.89	2
223	32.82	224	33.13	225	33.10	226	32.81	227	32.29	2
229	30.60	230	30.64	231	28.51	232	28.55			
301	-272.80									



## APPENDIX R. ITAS BATTERY THERMAL MASSES

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
1	-101	33.74	19.438	0	LOWER EQUIPMENT PLATE
2	-102	33.74	5.692	0	LOWER EQUIPMENT PLATE
3	-103	33.74	5.692	0	LOWER EQUIPMENT PLATE
4	-104	33.74	2.014	0	LOWER EQUIPMENT PLATE
5	-105	33.74	2.014	0	LOWER EQUIPMENT PLATE
6	-106	33.74	2.014	0	LOWER EQUIPMENT PLATE
7	-107	33.74	2.014	0	LOWER EQUIPMENT PLATE
8	201	30	2.169	0	BATTERY A
9	202	30	5.327	0	BATTERY A
10	203	30	3.3	0	BATTERY A
11	204	30	2.169	0	BATTERY A
12	205	30	5.327	0	BATTERY A
13	206	30	3.3	0	BATTERY A
14	301	30	3.805	0	DCS
15	302	30	6.342	0	DCS
16	303	30	7.610	0	DCS
17	304	30	3.805	0	DCS
18	305	30	6.342	0	DCS

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
 SHFT-F1Import Column Shift-F5Del/Pur  
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

SEQN	NodeNo	Temp-C	ThrMass	Dissip	Comment
19	306	30	7.610	0	DCS
20	401	30	2.169	0	BATTERY B
21	402	30	5.327	0	BATTERY B
22	403	30	3.3	0	BATTERY B
23	404	30	2.169	0	BATTERY B
24	405	30	5.327	0	BATTERY B
25	406	30	3.3	0	BATTERY B
26	-501	33.08	9.719	0	UPPER EQUIPMENT PLATE
27	-502	33.08	2.846	0	UPPER EQUIPMENT PLATE
28	-503	33.08	2.846	0	UPPER EQUIPMENT PLATE
29	-504	33.08	1.068	0	UPPER EQUIPMENT PLATE
30	-505	33.08	1.068	0	UPPER EQUIPMENT PLATE
31	-506	33.08	1.068	0	UPPER EQUIPMENT PLATE
32	-507	33.08	1.068	0	UPPER EQUIPMENT PLATE
33	-601	33.44	2.014	0	PANSAT STRUCTURE
34	-602	39.87	2.014	0	PANSAT STRUCTURE
35	-603	38.83	2.014	0	PANSAT STRUCTURE
36	-604	31.14	2.014	0	PANSAT STRUCTURE

Ctrl:Copy ITAS Node Data Entry For Thermal Analysis ESC:Quit

CTRL-F1Import ITAS\_NC UDC Allowed PgDn PgUp Home End  
 SHFT-F1Import Column Shift-F5Del/Pur  
 F1Save/Purge F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

CTRL-F1Import ITAS_NC      UDC Allowed      PgDn PgUp Home End
SHIFT-F1Import Column      Shift-F5Del/Pur
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

## APPENDIX S. BATTERY THERMAL MASS CALCULATIONS

BATTERY THERMAL CAPACITANCES								
NODE	area	thickness	volume	ro-Al	c-Al	conv fact	in-m	thr mass
101	122.6	0.25	30.65	2787	0.199	69.78	61024	19.43797
102	35.9	0.25	8.975	2787	0.199	69.78	61024	5.691868
103	35.9	0.25	8.975	2787	0.199	69.78	61024	5.691868
104	12.7	0.25	3.175	2787	0.199	69.78	61024	2.013558
105	12.7	0.25	3.175	2787	0.199	69.78	61024	2.013558
106	12.7	0.25	3.175	2787	0.199	69.78	61024	2.013558
107	12.7	0.25	3.175	2787	0.199	69.78	61024	2.013558
201	17.1	0.2	3.42	2787	0.199	69.78	61024	2.168935
202	42	0.2	8.4	2787	0.199	69.78	61024	5.327208
203	26	0.2	5.2	2787	0.199	69.78	61024	3.297795
204	17.1	0.2	3.42	2787	0.199	69.78	61024	2.168935
205	42	0.2	8.4	2787	0.199	69.78	61024	5.327208
206	26	0.2	5.2	2787	0.199	69.78	61024	3.297795
301	30	0.2	6	2787	0.199	69.78	61024	3.805148
302	50	0.2	10	2787	0.199	69.78	61024	6.341914
303	60	0.2	12	2787	0.199	69.78	61024	7.610297
304	30	0.2	6	2787	0.199	69.78	61024	3.805148
305	50	0.2	10	2787	0.199	69.78	61024	6.341914
306	60	0.2	12	2787	0.199	69.78	61024	7.610297
401	17.1	0.2	3.42	2787	0.199	69.78	61024	2.168935
402	42	0.2	8.4	2787	0.199	69.78	61024	5.327208
403	26	0.2	5.2	2787	0.199	69.78	61024	3.297795
404	17.1	0.2	3.42	2787	0.199	69.78	61024	2.168935
405	42	0.2	8.4	2787	0.199	69.78	61024	5.327208
406	26	0.2	5.2	2787	0.199	69.78	61024	3.297795
501	122.6	0.125	15.325	2787	0.199	69.78	61024	9.718983
502	35.9	0.125	4.4875	2787	0.199	69.78	61024	2.845934
503	35.9	0.125	4.4875	2787	0.199	69.78	61024	2.845934
504	12.7	0.125	1.5875	2787	0.199	69.78	61024	1.006779
505	12.7	0.125	1.5875	2787	0.199	69.78	61024	1.006779
506	12.7	0.125	1.5875	2787	0.199	69.78	61024	1.006779
507	12.7	0.125	1.5875	2787	0.199	69.78	61024	1.006779
601	50.8	0.0625	3.175	2787	0.199	69.78	61024	2.013558
602	50.8	0.0625	3.175	2787	0.199	69.78	61024	2.013558

603	50.8	0.0625	3.175	2787	0.199	69.78	61024	2.013558
604	50.8	0.0625	3.175	2787	0.199	69.78	61024	2.013558
605	50.8	0.0625	3.175	2787	0.199	69.78	61024	2.013558
606	50.8	0.0625	3.175	2787	0.199	69.78	61024	2.013558
607	50.8	0.0625	3.175	2787	0.199	69.78	61024	2.013558
608	50.8	0.0625	3.175	2787	0.199	69.78	61024	2.013558
701	12.6	0.2	2.52	2787	0.199	69.78	61024	1.598162
702	14.1	0.2	2.82	2787	0.199	69.78	61024	1.78842
703	72	0.2	14.4	2787	0.199	69.78	61024	9.132356
704	12.6	0.2	2.52	2787	0.199	69.78	61024	1.598162
705	14.1	0.2	2.82	2787	0.199	69.78	61024	1.78842
706	72	0.2	14.4	2787	0.199	69.78	61024	9.132356



## APPENDIX T. BATTERY CONDUCTANCE CALCULATIONS

BATTERY CONDUCTANCES							
From	To	width	th	area	length	k (Al)	conductance
201	202	5.25	0.2	1.05	5.625	4.31	0.804533333
201	205	5.25	0.2	1.05	5.625	4.31	0.804533333
201	203	3.25	0.2	0.65	6.625	4.31	0.422867925
201	206	3.25	0.2	0.65	6.625	4.31	0.422867925
202	204	3.25	0.2	0.65	6.625	4.31	0.422867925
202	203	8	0.2	1.6	4.25	4.31	1.622588235
202	206	8	0.2	1.6	4.25	4.31	1.622588235
203	205	8	0.2	1.6	4.25	4.31	1.622588235
203	204	3.25	0.2	0.65	6.625	4.31	0.422867925
204	206	3.25	0.2	0.65	6.625	4.31	0.422867925
204	205	3.25	0.2	0.65	5.625	4.31	0.498044444
205	206	8	0.2	1.6	4.25	4.31	1.622588235
301	302	5	0.2	1	8	4.31	0.53875
301	305	5	0.2	1	8	4.31	0.53875
301	303	6	0.2	1.2	7.5	4.31	0.6896
301	306	6	0.2	1.2	7.5	4.31	0.6896
302	304	5	0.2	1	8	4.31	0.53875
302	303	10	0.2	2	5.5	4.31	1.567272727
302	306	10	0.2	2	5.5	4.31	1.567272727
303	305	10	0.2	2	5.5	4.31	1.567272727
303	304	6	0.2	1.2	7.5	4.31	0.6896
304	306	6	0.2	1.2	7.5	4.31	0.6896
304	305	5	0.2	1	8	4.31	0.53875
305	306	10	0.2	2	5.5	4.31	1.567272727
401	402	5.25	0.2	1.05	5.625	4.31	0.804533333
401	405	5.25	0.2	1.05	5.625	4.31	0.804533333
401	403	3.25	0.2	0.65	6.625	4.31	0.422867925
401	406	3.25	0.2	0.65	6.625	4.31	0.422867925
402	404	3.25	0.2	0.65	6.625	4.31	0.422867925
402	403	8	0.2	1.6	4.25	4.31	1.622588235
402	406	8	0.2	1.6	4.25	4.31	1.622588235
403	405	8	0.2	1.6	4.25	4.31	1.622588235

403	404	3.25	0.2	0.65	6.625	4.31	0.422867925
404	406	3.25	0.2	0.65	6.625	4.31	0.422867925
404	405	5.25	0.2	1.05	5.625	4.31	0.804533333
405	406	8	0.2	1.6	4.25	4.31	1.622588235
1500	201			17.1	0.2	4.31	368.505
1500	202			42	0.2	4.31	905.1
1500	203			26	0.2	4.31	560.3
1500	204			17.1	0.2	4.31	368.505
1500	205			42	0.2	4.31	905.1
1500	206			26	0.2	4.31	560.3
1600	301			30	0.2	4.31	646.5
1600	302			50	0.2	4.31	1077.5
1600	303			60	0.2	4.31	1293
1600	304			30	0.2	4.31	646.5
1600	305			50	0.2	4.31	1077.5
1600	306			60	0.2	4.31	1293
1700	401			17.1	0.2	4.31	368.505
1700	402			42	0.2	4.31	905.1
1700	403			26	0.2	4.31	560.3
1700	404			17.1	0.2	4.31	368.505
1700	405			42	0.2	4.31	905.1
1700	406			26	0.2	4.31	560.3
206	102	3.25	7.13	23.1725	0.225	4.31	443.8821111
206	104	3.25	0.435	1.41375	0.225	4.31	27.08116667
206	105	3.25	0.435	1.41375	0.225	4.31	27.08116667
306	101	6	10	60	0.225	4.31	1149.333333
406	103	3.25	7.13	23.1725	0.225	4.31	443.8821111
406	106	3.25	0.435	1.41375	0.225	4.31	27.08116667
406	107	3.25	0.435	1.41375	0.225	4.31	27.08116667
703	501	7.13	7.13	50.8369	0.225	4.31	973.8090622
703	502	0.435	7.13	3.10155	0.225	4.31	59.41191333
703	503	0.435	7.13	3.10155	0.225	4.31	59.41191333
703	504	0.435	0.935	0.406725	0.225	4.31	7.791043333
703	505	0.435	0.935	0.406725	0.225	4.31	7.791043333
703	506	0.435	0.935	0.406725	0.225	4.31	7.791043333
703	507	0.435	0.935	0.406725	0.225	4.31	7.791043333

## APPENDIX U. BATTERY MODEL CONDUCTOR DATA ENTRY

```

ëëë Ctrl:Copyëëëëëëëëëëëëëë ITAS Conductor Data Entry ëëëëëëëëëëëëëëëë ESC:Quit f

```

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
1	1	1	101	1000	L	GEOMETRY TO LOWER PLATE NODE
2	1	2	102	1000	L	GEOMETRY TO LOWER PLATE NODE
3	1	3	103	1000	L	GEOMETRY TO LOWER PLATE NODE
4	1	4	104	1000	L	GEOMETRY TO LOWER PLATE NODE
5	1	5	105	1000	L	GEOMETRY TO LOWER PLATE NODE
6	1	6	106	1000	L	GEOMETRY TO LOWER PLATE NODE
7	1	7	107	1000	L	GEOMETRY TO LOWER PLATE NODE
8	1	8	201	1000	L	GEOMETRY TO BATTERY A NODE
9	1	9	202	1000	L	GEOMETRY TO BATTERY A NODE
10	1	10	203	1000	L	GEOMETRY TO BATTERY A NODE
11	1	11	204	1000	L	GEOMETRY TO BATTERY A NODE
12	1	12	205	1000	L	GEOMETRY TO BATTERY A NODE
13	1	13	206	1000	L	GEOMETRY TO BATTERY A NODE
14	1	14	301	1000	L	GEOMETRY TO DCS NODE
15	1	15	302	1000	L	GEOMETRY TO DCS NODE
16	1	16	303	1000	L	GEOMETRY TO DCS NODE
17	1	17	304	1000	L	GEOMETRY TO DCS NODE
18	1	18	305	1000	L	GEOMETRY TO DCS NODE

```

#####
CTRL-F1Import ITAS_NC      ALT-F3AutoMLI      UDC Allowed      PgDn PgUp Home
SHIFT-F1Import Column      Shift-F3AutoCHT      Shift-F5Del/Pur      End
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search
#####

```

```

ëëë Ctrl:Copyëëëëëëëëëëëëëë ITAS Conductor Data Entry ëëëëëëëëëëëëëëëë ESC:Quit f

```

SqNo	FACTOR	From	To	Cond. Value	L/R	Description
19	1	19	306	1000	L	GEOMETRY TO DCS NODE
20	1	20	401	1000	L	GEOMETRY TO BATTERY B NODE
21	1	21	402	1000	L	GEOMETRY TO BATTERY B NODE
22	1	22	403	1000	L	GEOMETRY TO BATTERY B NODE
23	1	23	404	1000	L	GEOMETRY TO BATTERY B NODE
24	1	24	405	1000	L	GEOMETRY TO BATTERY B NODE
25	1	25	406	1000	L	GEOMETRY TO BATTERY B NODE
26	1	26	501	1000	L	GEOMETRY TO UPPER PLATE
27	1	27	502	1000	L	GEOMETRY TO UPPER PLATE
28	1	28	503	1000	L	GEOMETRY TO UPPER PLATE
29	1	29	504	1000	L	GEOMETRY TO UPPER PLATE
30	1	30	505	1000	L	GEOMETRY TO UPPER PLATE
31	1	31	506	1000	L	GEOMETRY TO UPPER PLATE
32	1	32	506	1000	L	GEOMETRY TO UPPER PLATE
33	1	33	601	1000	L	GEOMETRY TO STRUCTURE NODE
34	1	34	602	1000	L	GEOMETRY TO STRUCTURE NODE
35	1	35	603	1000	L	GEOMETRY TO STRUCTURE NODE
36	1	36	604	1000	L	GEOMETRY TO STRUCTURE NODE

```

CTRL-F1Import ITAS_NC      ALT-F3AutoMLI      UDC Allowed      PgDn PgUp Home
SHIFT-F1Import Column      Shift-F3AutoCHT      Shift-F5Del/Pur      End
      F1Save/Purge      F2Help F3AutoGen F4Purge F5Delete F7Mark/UnMark F10Search

```

[illegible]





SqNo	FACTOR	From	To	Cond. Value	L/R	Description
109	1	703	502	27.08	L	EPS TO UPPER PLATE
110	1	703	503	27.08	L	EPS TO UPPER PLATE
111	1	703	504	7.791	L	EPS TO UPPER PLATE
112	1	703	505	7.791	L	EPS TO UPPER PLATE
113	1	703	506	7.791	L	EPS TO UPPER PLATE
114	1	703	507	7.791	L	EPS TO UPPER PLATE

```

aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaV
CTRL-F1Import ITAS_NC      ALT-F3AutoMLI    UDC Allowed          PgDn PgUp Home
SHIFT-F1Import Column     Shift-F3AutoCHT   Shift-F5Del/Pur      End
      F1Save/Purge        F2Help F3AutoGen F4Purge F5Delete  F7Mark/UnMark F10Search

```

## APPENDIX V. BATTERY THERMAL ANALYSIS RESULTS

```
***** PC-ITAS *****  
*LINE NO.      1 to      18      RESULTS REVIEW  
*****  
Date: 09/15/94                                     Time: 17:08:37.10
```

### Thermal Analysis Parameters

1. Solution Method:1.Steady-State 2.Transient 3. (1&2).....	1
2. Solution Time Step .....(minutes).....	0.10
3. Final Time (minutes);if <0 then no of orbs.....	-1.00
4. Starting Temperature .....(Kelvin ).....	300.00
5. Temperature Print Interval (minutes).....	20
6. No. of Iterations For Convergence (NLOOP).....	9999
7. Temperature Unit 1:K, 2:C, 3:F, 4:R.....	2
8. Solution Accuracy Parameter (not used).....	130
9. Solution Convergence Parameter (not used).....	1.30
10. Solution Tolerance (ARLXCA, DRLXCA).....	0.00100
11. Transient Solution Stability Factor (not used).....	0.850
12. Include User-Defined Network.....(Y/N).....	N

Use PgDn PgUp Home End F1Save F10Search For ESCQuit/Main Menu

```

Oaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa PC-ITAS aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
*LINE NO.      19 to      36      RESULTS REVIEW
aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa
13. Print RADK, POWER.....(Y/N)..... N
14. Print Transient Time/Temperature...(Y/N)..... N
15. Starting Temperatures Forced (No.4)(Y/N)..... N
16. Thermal Analyses Without Orbital Loads (Y/N)..... N
17. Stand-Alone Thermal Analyzer (ITAS-Format Models)..... N
18. No. of Isolated Cavities (RADK files)..... 0

```

\*ITAS THERMAL ANALYSIS\*

## ITAS ABSORBED HEAT RATES FROM ORBITAL INCIDENT & IR AND UV RADIANCES

Date: 09/15/94 Time: 17:08:37.10

Use PgDn PgUp Home End      F1Save    F10Search For    ESCQuit/Main Menu

Date: 09/16/94

Time: 10:17:03.10

.....

Use PgDn PgUp Home End      F1Save    F10Search For    ESCQuit/Main Menu

.....

Use PgDn PgUp Home End      F1Save    F10Search For    ESCQuit/Main Menu



TOTAL CARDS ENCOUNTERED:	2092	
TOTAL THERMAL MASSES USED (W-Min/C)=	7102.07	
TOTAL THERMAL MASSES USED (BTU/F )=	224.440	

ITAS STEADY-STATE SOLUTION ALGORITHM (SUCCESSIVE POINT ITERATION) PARAMETERS:  
ARLXCA=0.10000E-02, DRLXCA=0.10000E-02 NLOOP= 9999

Use PgDn PgUp Home End      F1Save      F10Search For      ESCQuit/Main Menu

T	13=	33.69 T	14=	33.72 T	15=	33.72 T	16=	33.72
T	17=	33.72 T	18=	33.72 T	19=	33.69 T	20=	33.70
T	21=	33.70 T	22=	33.70 T	23=	33.70 T	24=	33.69
T	25=	33.69 T	26=	33.08 T	27=	33.08 T	28=	33.08
T	29=	33.08 T	30=	33.08 T	31=	33.08 T	32=	33.08
T	33=	33.44 T	34=	39.87 T	35=	38.83 T	36=	31.14
T	37=	30.79 T	38=	33.26 T	39=	33.26 T	40=	28.56
T	41=	33.00 T	42=	33.00 T	43=	33.97 T	44=	33.00
T	45=	33.00 T	46=	33.97 T	47=	-273.16 T	101=	33.74
T	102=	33.74 T	103=	33.74 T	104=	33.74 T	105=	33.74
T	106=	33.74 T	107=	33.74 T	201=	33.69 T	202=	33.69
T	203=	33.69 T	204=	33.69 T	205=	33.69 T	206=	33.70
T	301=	33.72 T	302=	33.72 T	303=	33.72 T	304=	33.72
T	305=	33.72 T	306=	33.72 T	401=	33.70 T	402=	33.70
T	403=	33.70 T	404=	33.70 T	405=	33.69 T	406=	33.71
T	501=	33.08 T	502=	33.08 T	503=	33.08 T	504=	33.08
T	505=	33.08 T	506=	33.08 T	507=	33.08 T	601=	33.44
T	602=	39.87 T	603=	38.83 T	604=	31.14 T	605=	30.72

177

PC-ITAS RESULTS REVIEW									
*LINE NO. 1459 to 1476									
T 606=	33.26	T 607=	33.26	T 608=	28.56	T 701=	33.00		
T 702=	33.00	T 703=	34.00	T 704=	33.00	T 705=	33.00		
T 706=	34.00	T 1500=	33.69	T 1600=	33.72	T 1700=	33.70		

ASCENDING NODE NUMBER : TEMPERATURE

\*\*\*\*\*

### ITAS STEADY-STATE SOLUTION (SUCCESSIVE POINT ITERATION)

NO. OF ITERATIONS= 68 TOTAL INPUT ENERGY (W)= 9.6800

SYSTEM ENERGY BALANCE (W) = 5.1598 ( 53.303 %)

\*\*\*\*\*

T 1= 33.710 T 2= 33.730 T 3= 33.730 T 4= 33.739

T 5= 33.739 T 6= 33.739 T 7= 33.739 T 8= 33.688

T 9= 33.684 T 10= 33.688 T 11= 33.688 T 12= 33.687

T 13= 33.689 T 14= 33.721 T 15= 33.716 T 16= 33.722

T	17=	33.722	T	18=	33.716	T	19=	33.691	T	20=	33.695
---	-----	--------	---	-----	--------	---	-----	--------	---	-----	--------

T	21=	33.697	T	22=	33.696	T	23=	33.696	T	24=	33.692
T	25=	33.693	T	26=	33.693	T	27=	33.693	T	28=	33.693

T	25=	33.693	T	26=	33.080	T	27=	33.080	T	28=	33.080
T	29=	33.080	T	30=	33.080	T	31=	33.080	T	32=	33.080

T 29= 33.080 T 30= 33.080 T 31= 33.080 T 32= 33.080

Use PgDn PgUp Home End

F1Save

F10Search For

ESCQuit/Main Menu

PC-ITAS  
°LINE NO. 1477 to 1494 RESULTS REVIEW

١

T 33= 33.439 T 34= 39.867 T 35= 38.828 T 36= 31.140

T	37=	30.790	T	38=	33.259	T	39=	33.260	T	40=	28.561
---	-----	--------	---	-----	--------	---	-----	--------	---	-----	--------

T 41= 32.996 T 42= 32.996 T 43= 33.972 T 44= 32.996

T 45= 32.996 T 46= 33.966 T 47= -273.159 T 101= 33.740

T 102= 33.740 T 103= 33.740 T 104= 33.740 T 105= 33.740

T 106= 33.740 T 107= 33.740 T 201= 33.689 T 202= 33.687

T 203= 33.689 T 204= 33.688 T 205= 33.688 T 206= 33.702

T 301= 33.722 T 302= 33.719 T 303= 33.722 T 304= 33.722

T 305= 33.719 T 306= 33.719 T 401= 33.696 T 402= 33.697

T 403= 33.697 T 404= 33.697 T 405= 33.695 T 406= 33.706

T 501= 33.080 T 502= 33.080 T 503= 33.080 T 504= 33.080

T 505= 33.080 T 506= 33.080 T 507= 33.080 T 601= 33.440

T 602= 39.870 T 603= 38.830 T 604= 31.140 T 605= 30.790

T 606= 33.260 T 607= 33.260 T 608= 28.560 T 701= 33.000

T 702= 33.000 T 703= 34.000 T 704= 33.000 T 705= 33.000

T	706=	34.000	T	1500=	33.691	T	1600=	33.722	T	1700=	33.698
---	------	--------	---	-------	--------	---	-------	--------	---	-------	--------

ASCENDING NODE NUMBER : IMPRESSED Q

Q 1= 0.000 Q 2= 0.000 Q 3= 0.000 Q 4= 0.000

Use PgDn PgUp Home End

F1Save

F10Search For

ESCQuit/Main Menu

```

PgDn PgUp Home End      ITAS Time ( ) / Temperature ( ) Results      ^^
=====
Tempááááç  ÖááNode      ÖáááááááPlot Flags (X or Y)  □
□
□ Time °      103      104      105      106      107      201      202□
□ 63.95 º      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 65.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 67.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 69.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 71.95      33.74      33.74      33.74      33.74      33.74      33.72      33.71□
□ 73.95      33.74      33.74      33.74      33.74      33.74      33.72      33.71□
□ 75.95      33.74      33.74      33.74      33.74      33.74      33.72      33.71□
□ 77.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 79.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 81.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 83.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 85.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 87.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 89.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 91.95      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 92.33      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
□ 92.33      33.74      33.74      33.74      33.74      33.74      33.71      33.71□
=====
S-F3Save ASCII
F1Plot F2Help F3Save Binary F4SelPlot F8PageLeft F9PageRight ESCQuit

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PgDn PgUp Home End      ITAS Time ( ) / Temperature ( ) Results      ^^
=====
Tempááááç  ÖááNode      ÖáááááááPlot Flags (X or Y)  □
□
□ Time °      203      204      205      206      301      302      303□
□ 63.95 º      33.71      33.71      33.71      33.71      33.72      33.72      33.72□
□ 65.95      33.71      33.71      33.71      33.72      33.72      33.72      33.72□
□ 67.95      33.71      33.71      33.71      33.72      33.73      33.72      33.73□
□ 69.95      33.72      33.71      33.71      33.72      33.73      33.73      33.73□
□ 71.95      33.72      33.72      33.72      33.72      33.73      33.73      33.73□
□ 73.95      33.72      33.72      33.72      33.72      33.73      33.73      33.73□
□ 75.95      33.72      33.72      33.71      33.72      33.73      33.72      33.73□
□ 77.95      33.71      33.71      33.71      33.71      33.72      33.72      33.73□
□ 79.95      33.71      33.71      33.71      33.71      33.72      33.72      33.72□
□ 81.95      33.71      33.71      33.71      33.71      33.72      33.72      33.72□
□ 83.95      33.71      33.71      33.71      33.71      33.72      33.72      33.72□
□ 85.95      33.71      33.71      33.71      33.71      33.72      33.72      33.72□
□ 87.95      33.71      33.71      33.71      33.71      33.72      33.72      33.72□
□ 89.95      33.71      33.71      33.71      33.71      33.72      33.72      33.72□
□ 91.95      33.71      33.71      33.71      33.71      33.72      33.72      33.72□
□ 92.33      33.71      33.71      33.71      33.71      33.72      33.72      33.72□
□ 92.33      33.71      33.71      33.71      33.71      33.72      33.72      33.72□
=====
S-F3Save ASCII
F1Plot F2Help F3Save Binary F4SelPlot F8PageLeft F9PageRight ESCQuit

```

```

PgDn PgUp Home End      ITAS Time ( ) / Temperature ( ) Results
=====
Tempááááç ÔááNode      ÔáááááááPlot Flags (X or Y)
.
.
Time      .      304      305      306      401      402      403      404
63.95 á    33.72      33.72      33.72      33.71      33.71      33.71      33.71
65.95      33.72      33.72      33.72      33.71      33.71      33.71      33.71
67.95      33.73      33.72      33.73      33.71      33.72      33.71      33.71
69.95      33.73      33.73      33.73      33.72      33.72      33.72      33.72
71.95      33.73      33.73      33.73      33.72      33.72      33.72      33.72
73.95      33.73      33.73      33.73      33.72      33.72      33.72      33.72
75.95      33.73      33.72      33.72      33.72      33.72      33.72      33.72
77.95      33.73      33.72      33.72      33.71      33.72      33.72      33.72
79.95      33.72      33.72      33.72      33.71      33.71      33.71      33.71
81.95      33.72      33.72      33.72      33.71      33.71      33.71      33.71
83.95      33.72      33.72      33.72      33.71      33.71      33.71      33.71
85.95      33.72      33.72      33.72      33.71      33.71      33.71      33.71
87.95      33.72      33.72      33.72      33.71      33.71      33.71      33.71
89.95      33.72      33.72      33.72      33.71      33.71      33.71      33.71
91.95      33.72      33.72      33.72      33.71      33.71      33.71      33.71
92.33      33.72      33.72      33.72      33.71      33.71      33.71      33.71
92.33      33.72      33.72      33.72      33.71      33.71      33.71      33.71
=====

```

S-F3Save ASCII

F1Plot F2Help F3Save Binary F4SelPlot F8PageLeft F9PageRight ESCQuit

```

PgDn PgUp Home End      ITAS Time ( ) / Temperature ( ) Results
=====
Tempááááç ÔááNode      ÔáááááááPlot Flags (X or Y)
.
.
Time      .      405      406      501      502      503      504      505
63.95 á    33.71      33.71      33.08      33.08      33.08      33.08      33.08
65.95      33.71      33.72      33.08      33.08      33.08      33.08      33.08
67.95      33.71      33.72      33.08      33.08      33.08      33.08      33.08
69.95      33.71      33.72      33.08      33.08      33.08      33.08      33.08
71.95      33.72      33.72      33.08      33.08      33.08      33.08      33.08
73.95      33.72      33.72      33.08      33.08      33.08      33.08      33.08
75.95      33.72      33.72      33.08      33.08      33.08      33.08      33.08
77.95      33.71      33.72      33.08      33.08      33.08      33.08      33.08
79.95      33.71      33.71      33.08      33.08      33.08      33.08      33.08
81.95      33.71      33.71      33.08      33.08      33.08      33.08      33.08
83.95      33.71      33.71      33.08      33.08      33.08      33.08      33.08
85.95      33.71      33.71      33.08      33.08      33.08      33.08      33.08
87.95      33.71      33.71      33.08      33.08      33.08      33.08      33.08
89.95      33.71      33.71      33.08      33.08      33.08      33.08      33.08
91.95      33.71      33.71      33.08      33.08      33.08      33.08      33.08
92.33      33.71      33.71      33.08      33.08      33.08      33.08      33.08
92.33      33.71      33.71      33.08      33.08      33.08      33.08      33.08
=====

```

S-F3Save ASCII

F1Plot F2Help F3Save Binary F4SelPlot F8PageLeft F9PageRight ESCQuit







```

PgDn PgUp Home End ITAS Time ( ) / Temperature ( ) Results ^
Tempááááç ÖááNode
Time ° 15 16 17 18 19 20 21a
0.00 á 26.84 26.84 26.84 26.84 26.84 26.84a
1.95 26.99 27.00 26.99 27.15 26.93 26.94a
3.95 27.18 27.19 27.19 27.18 27.06 27.07a
5.95 27.37 27.38 27.38 27.37 27.18 27.19a
7.95 27.55 27.56 27.56 27.55 27.30 27.31a
9.95 27.73 27.74 27.73 27.73 27.42 27.43a
11.95 27.90 27.91 27.91 27.90 27.54 27.55a
13.95 28.07 28.08 28.07 28.07 27.65 27.66a
15.95 28.23 28.24 28.23 28.23 27.77 27.77a
17.95 28.38 28.39 28.39 28.38 27.88 27.88a
19.95 28.53 28.54 28.54 28.53 27.98 27.99a
21.95 28.68 28.69 28.68 28.68 28.09 28.10a
23.95 28.82 28.83 28.82 28.82 28.19 28.20a
25.95 28.96 28.96 28.96 28.96 28.29 28.30a
27.95 29.09 29.10 29.09 29.09 28.39 28.40a
29.95 29.22 29.22 29.22 29.22 28.49 28.49a
31.95 29.34 29.35 29.34 29.34 28.58 28.59a
S-F3Save ASCII
F1Plot F2Help F3Save Binary F4SelPlot F8PageLeft F9PageRight ESCQuit

```

PgDn	PgUp	Home	End	ITAS	Time ( ) / Temperature ( )	Results	Flags (X or Y)
Temp	ááááá	°	°	°	°	°	°
Time	°	°	°	°	°	°	°
0.00	26.84	26.84	26.84	26.84	26.84	26.84	26.84
1.95	26.94	26.94	26.94	26.94	26.94	26.94	26.94
3.95	27.06	27.06	27.06	27.06	27.06	27.06	27.06
5.95	27.19	27.19	27.19	27.19	27.19	27.19	27.19
7.95	27.31	27.31	27.31	27.31	27.31	27.31	27.31
9.95	27.43	27.43	27.43	27.43	27.43	27.43	27.43
11.95	27.54	27.54	27.54	27.54	27.54	27.54	27.54
13.95	27.66	27.66	27.66	27.66	27.66	27.66	27.66
15.95	27.77	27.77	27.77	27.77	27.77	27.77	27.77
17.95	27.88	27.88	27.88	27.88	27.88	27.88	27.88
19.95	27.99	27.99	27.99	27.99	27.99	27.99	27.99
21.95	28.09	28.09	28.09	28.09	28.09	28.09	28.09
23.95	28.19	28.19	28.19	28.19	28.19	28.19	28.19
25.95	28.29	28.29	28.29	28.29	28.29	28.29	28.29
27.95	28.39	28.39	28.39	28.39	28.39	28.39	28.39
29.95	28.49	28.49	28.49	28.49	28.49	28.49	28.49
31.95	28.58	28.58	28.58	28.58	28.58	28.58	28.58

F1Plot F2Help F3Save Binary F4SelPlot F8PageLeft F9PageRight ESCQuit  
 S-F3Save ASCII







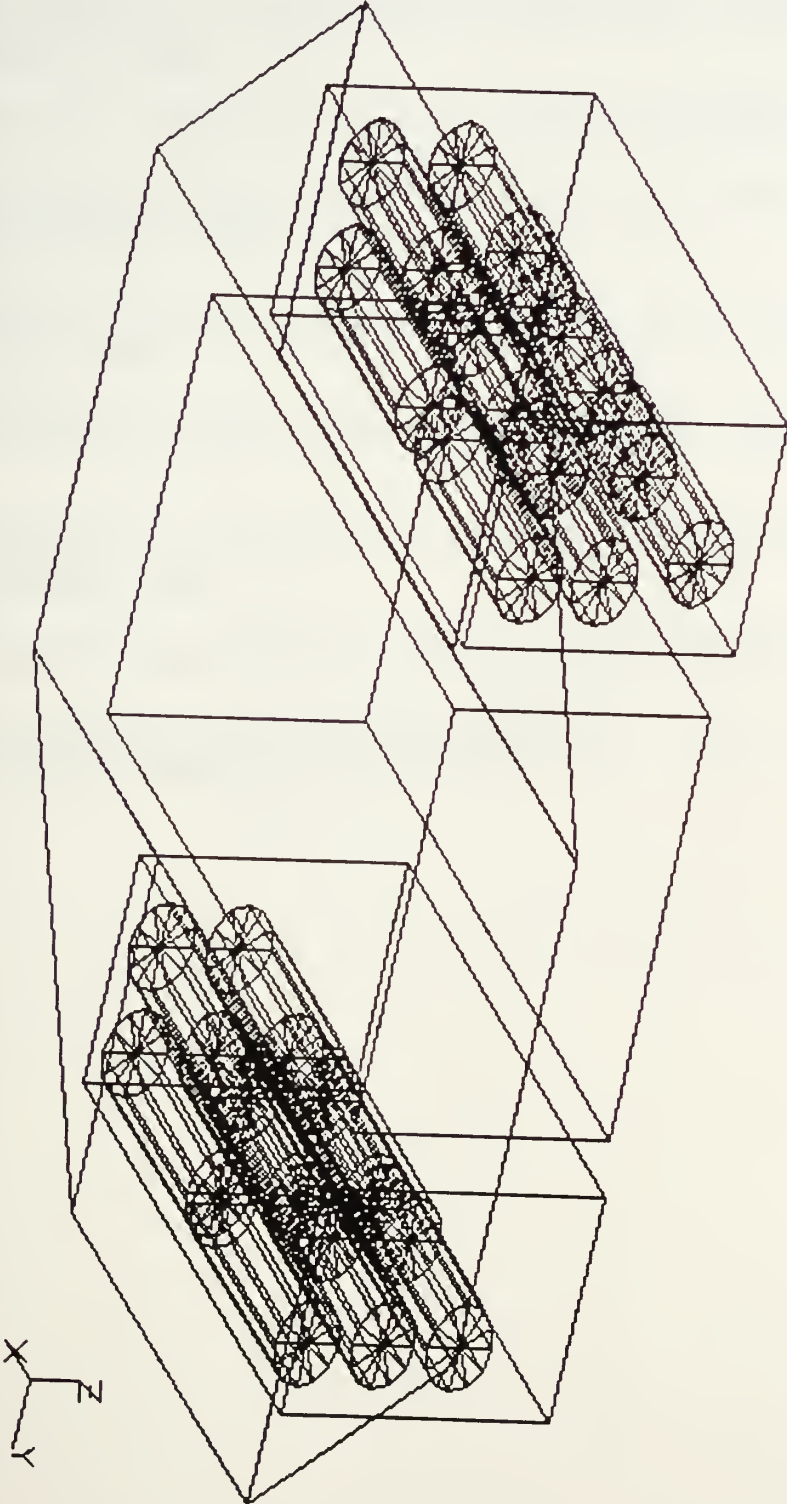
PgDn	PgUp	Home	End	ITAS	Time ( ) / Temperature ( )	Results	Flags (X or Y)
Temp	0.00	30.68	30.68	30.68	30.74	33.08	33.08
Temp	1.95	30.69	30.69	30.69	30.74	33.08	33.08
Temp	3.95	30.70	30.70	30.70	30.74	33.08	33.08
Temp	5.95	30.70	30.70	30.70	30.73	33.08	33.08
Temp	7.95	30.71	30.71	30.71	30.73	33.08	33.08
Temp	9.95	30.71	30.71	30.71	30.73	33.08	33.08
Temp	11.95	30.71	30.71	30.71	30.73	33.08	33.08
Temp	13.95	30.72	30.72	30.72	30.73	33.08	33.08
Temp	15.95	30.72	30.72	30.72	30.73	33.08	33.08
Temp	17.95	30.72	30.72	30.72	30.73	33.08	33.08
Temp	19.95	30.73	30.73	30.73	30.73	33.08	33.08
Temp	21.95	30.73	30.73	30.73	30.73	33.08	33.08
Temp	23.95	30.73	30.73	30.73	30.73	33.08	33.08
Temp	25.95	30.74	30.74	30.74	30.73	33.08	33.08
Temp	27.95	30.74	30.74	30.74	30.74	33.08	33.08
Temp	29.95	30.74	30.74	30.74	30.74	33.08	33.08
Temp	31.95	30.74	30.74	30.74	30.74	33.08	33.08

F1Plot F2Help F3Save Binary F4SelPlot F8PageLeft F9PageRight ESCQuit  
 S-F3Save ASCII





APPENDIX W. BATTERY THERMAL MODEL (INWARD VIEWING)



THE JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION  
PUBLISHED WEEKLY  
CHICAGO, ILL., U.S.A.



## LIST OF REFERENCES

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